Module Catalogue

Master of Science (M.Sc.) in the subject Microsystems Engineering
Subject-specific academic regulations from the 19th of August 2005 amended on the 03rd of November 2014

Institut für Mikrosystemtechnik
Technische Fakultät
Albert-Ludwigs-Universität Freiburg
Introduction

An essential feature of modern intelligent systems is their ability to interact with the environment or with the user. So a mobile phone is not only able to take language but also images, its location position, vibration or the weather. The mobile phone shows also further informations in the form of speech, sound, vibration, color images or radio signals. For all these information channels microsystems are needed, which transform physical or chemical signals into electrical impulses. Thus, one needs for micro-sensors and micro actuators, the input for the reaction. Intelligent, interactive systems are changing our entire living environment and the technology crucial. New applications of micro-systems can be found in the medical, automotive or mechanical engineering and they make people's lives safer, more comfortable and environmentally friendly. In order to design and manufacture microsystems have to master the associated technologies and methods of microsystem technology well. This essential “tools” of modern engineering we convey in our Bachelor microsystems technology. This conclusion is the basis for specialization and further professional development of students. Master's degree in the knowledge about the applications of microsystems is becoming increasingly important and can be oriented approximately toward medical, biology and automotive electronics. The professional activity fields the graduates are then open depending on the inclination of research and development, production, technical writing, or even the management of their own company.

This module catalogue has been compiled according to the academic regulations for the study program Master of Science in the subject Microsystems Engineering in the version of 19th of august 2005, as amended on 03rd of november 2014. The academic regulations define the modules which constitute the curriculum as well as how the curriculum is divided into terms and areas.

In the module descriptions it is stated how many credit points a student receives for a specific course, course work and examination, according to the „European Credit Transfer and Accumulation System“ (short: ECTS system). These credit points define the student's work load (one point is equivalent to a work load of 30 hours). They also define the weighting of a module within the whole study program and its impact on the final average grade. The recommended number of ECTS points to be completed per term is 30.

Students of the M. Sc. Microsystems Engineering have to complete at least 120 ECTS points, which usually requires 4 terms.

You will find more information about the exam regulations of the Master's program at http://www.tf.uni-freiburg.de/studies/degree_programmes/master/msc-mse
Structure of this module catalogue

1. Parts
The Master of Science program is divided into mandatory and elective part.

2. Modules
A module is a self-contained unit within a scientific topic or area and may consist of several part-modules. Modules can consist of one or more courses and examinations and coursework.

3. Types of courses
A course is the smallest unit described in this catalogue. There are different types of courses, including lectures, exercises, laboratory courses, seminars, ...

4. Overview
The Master’s programme is divided into the following two areas:
- Mandatory Modules
- Elective Modules

The student have to complete all the described modules in mandatory modules.
The elective part is divided in 9 different concentration areas:
1. Circuits and systems
2. Design and simulation
3. Life sciences: Biomedical engineering
4. Life sciences: Lab-on-a-chip
5. Materials
6. MEMS Processing
7. Photonics
8. Sensors and actuators
9. Personal Profile

Student has to choose 2 concentration areas. Within each concentration area students have to complete modules with a minimum of 9 ECTS points. In total, in the elective part students have to complete modules with a amount of minimum 24 ECTS points.
Study plan

The curricula - or study plans - are meant to help the students to organise their studies. It is not mandatory to take the courses in the same order displayed in the curriculum. The curriculum, sorted by terms, is given below:

<table>
<thead>
<tr>
<th>Term</th>
<th>Module</th>
<th>Area</th>
<th>hours</th>
<th>ECTS</th>
<th>cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Microelectronics</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>1</td>
<td>Micromechanics</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>1</td>
<td>Micro-optics</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>1</td>
<td>Sensors and Actuators</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>1</td>
<td>Probability and Statistics</td>
<td>Mathematics</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>1</td>
<td>MST Technologies and Processes</td>
<td>Advanced MSE</td>
<td>V 4</td>
<td>Ü 0</td>
<td>S 0</td>
</tr>
<tr>
<td>1</td>
<td>MST Design Laboratory I</td>
<td>Advanced MSE</td>
<td>V 0</td>
<td>Ü 0</td>
<td>S 2</td>
</tr>
<tr>
<td>Term 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MST Design Laboratory II</td>
<td>Advanced MSE</td>
<td>V 0</td>
<td>Ü 0</td>
<td>S 2</td>
</tr>
<tr>
<td>2</td>
<td>Assembly and Packaging Technology</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 1</td>
<td>S 0</td>
</tr>
<tr>
<td>2</td>
<td>Micro-fluidics</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>2</td>
<td>Biomedical Microsystems</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>2</td>
<td>Dynamics of MEMS</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 2</td>
<td>S 0</td>
</tr>
<tr>
<td>2</td>
<td>Micro-actuators</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 1</td>
<td>S 0</td>
</tr>
<tr>
<td>2</td>
<td>Signal Processing</td>
<td>Advanced MSE</td>
<td>V 2</td>
<td>Ü 1</td>
<td>S 0</td>
</tr>
<tr>
<td>Term 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 1</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 1</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 1</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 1</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 2</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 2</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Concentrationfield 2</td>
<td>MSEConcentration</td>
<td>E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Term 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Master’s Thesis</td>
<td>-</td>
<td>M</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Presentation of the Thesis</td>
<td>-</td>
<td>M</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Description: You can find the weekly working hours in the column hours which are structures in the types of the courses (V= lecture, Ü= exercises, S= seminar, P= laboratory/project)
Table of content

Introduction .................................................................................................................. 2
Structure of this module catalogue ........................................................................ 3
Study plan .................................................................................................................. 4
Table of content ........................................................................................................ 5

Mandatory Modules ......................................................................................................... 15
Conclusion Module ......................................................................................................... 15
Assembly and packaging technologies ..................................................................... 16
Biomedical Microsystems ............................................................................................. 16
Dynamics of MEMS ....................................................................................................... 17
Micro-actuators .............................................................................................................. 17
Micro-electronics ........................................................................................................... 18
Micro-fluidics ................................................................................................................ 18
Micro-mechanics ........................................................................................................... 19
Micro-optics ................................................................................................................... 19
MST Design Laboratory ................................................................................................. 20
MST Design Laboratory I .............................................................................................. 20
MST Design Laboratory II ............................................................................................ 20
MST technologies and processes ............................................................................... 21
Probability and statistics ............................................................................................ 21
Sensors ......................................................................................................................... 22
Signal Processing .......................................................................................................... 22

Elective Modules Master of Science in Microsystems Engineering/ Microsystemtechnik
Concentrations ............................................................................................................... 33
Concentration-Area in Microsystems Engineering – Circuits and Systems ............ 34
Bauelemente und Schaltungen der Leistungselektronik / Power Electronic Circuits and Devices .................................................................................................................. 34
Drahtlose Sensorsysteme / Wireless Sensor Systems .................................................. 35
Eingebettete Regelungssysteme Projekt / Embedded Control Project ................... 36
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells ................................................................. 37
Entwurf Analog-CMOS Schaltungen / Analog CMOS Circuit Design ................. 38
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design ..................................................................................................................... 39
Flugregelung Laboratory / Flight Control Laboratory ............................................... 40
Fortgeschrittene Eingebettete Systeme Laboratory / Advanced Embedded Systems Laboratory ................................................................................................................ 40
Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics ........ 41
Fortgeschrittenes Praktikum für Mikrocontroller / Advanced Laboratory in Microcontroller ..................................................................................................................... 42
Magnetische Mikrosysteme / Magnetic Microsystems ............................................. 43
Mikroakustik / Microacoustics .................................................................................... 43
<table>
<thead>
<tr>
<th>Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mikroakustik - Seminar / Microacoustics - Seminar ................. 8191</td>
</tr>
<tr>
<td>Modellbildung und Systemidentifikation / Modelling and System Identification .......... 8393</td>
</tr>
<tr>
<td>Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control .......... 8595</td>
</tr>
<tr>
<td>Numerische Optimale Steuerung mit Differentiell-Algebraischen Gleichungen / Numerical Optimal Control with Differential Algebraic Equations .......... 8898</td>
</tr>
<tr>
<td>Numerische Optimierung / Numerical Optimization .......... 91101</td>
</tr>
<tr>
<td>Numerische Optimierung Projekt / Numerical Optimization Project .......... 94104</td>
</tr>
<tr>
<td>Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project .......... 96106</td>
</tr>
<tr>
<td>Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control .......... 98108</td>
</tr>
<tr>
<td>Optik-Laboratory Grundlagen / Basic Optics Laboratory .......... 101111</td>
</tr>
<tr>
<td>Optik-Laboratory Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory .......... 1041114</td>
</tr>
<tr>
<td>Optimale Steuerung und Estimation / Optimal Control and Estimation .......... 1081118</td>
</tr>
<tr>
<td>Optische Materialien / Optical Materials .......... 111121</td>
</tr>
<tr>
<td>Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking .......... 117127</td>
</tr>
<tr>
<td>Optische MEMS / Optical MEMS .......... 120130</td>
</tr>
<tr>
<td>Optoelektronik / Optoelectronics .......... 123133</td>
</tr>
<tr>
<td>Rennautoregelung – Laboratory / Race Car Control Laboratory .......... 127137</td>
</tr>
<tr>
<td>RF- und Mikrowellen Design Kurs / RF- and Microwave Design Course .......... 130140</td>
</tr>
<tr>
<td>RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits .......... 133143</td>
</tr>
<tr>
<td>RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems .......... 136146</td>
</tr>
<tr>
<td>Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators .......... 139149</td>
</tr>
<tr>
<td>Systemtheorie und Regelungstechnik II / Systems theory and automatic control II .......... 141151</td>
</tr>
<tr>
<td>VLSI Systementwurf / VLSI System Design .......... 144154</td>
</tr>
<tr>
<td>Zuverlässigkeitstechnik / Reliability Engineering .......... 147157</td>
</tr>
<tr>
<td>Concentration-Area Microsystems Engineering – Design and simulation .......... 150160</td>
</tr>
<tr>
<td>Computerunterstützte und mechanische Konstruktion / Computer-Aided and mechanic Design .......... 150160</td>
</tr>
<tr>
<td>Eingebettete Regelungssysteme Projekt / Embedded Control Project .......... 152162</td>
</tr>
<tr>
<td>Flugregelung Laboratory / Flight Control Laboratory .......... 154164</td>
</tr>
<tr>
<td>Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Methode .......... 157167</td>
</tr>
<tr>
<td>Kontinuumsmechanik I / Continuum mechanics I .......... 159169</td>
</tr>
<tr>
<td>Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises .......... 161171</td>
</tr>
<tr>
<td>Kontinuumsmechanik II / Continuum mechanics II .......... 163173</td>
</tr>
<tr>
<td>Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises .......... 165175</td>
</tr>
<tr>
<td>Lattice Gas Methoden / Lattice Gas Methods .......... 167177</td>
</tr>
<tr>
<td>Modellbildung und Systemidentifikation / Modelling and System Identification</td>
</tr>
<tr>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Nichtlineare Modell-Prediktive Regelung / Nonlinear Model Predictive Control</td>
</tr>
<tr>
<td>Numerische Optimale Steuerung mit Differentiell-Algebraischen Gleichungen / Numerical Optimal Control with Differential Algebraic Equations</td>
</tr>
<tr>
<td>Numerische Optimierung / Numerical Optimization</td>
</tr>
<tr>
<td>Numerische Optimierung Projekt / Numerical Optimization Project</td>
</tr>
<tr>
<td>Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project</td>
</tr>
<tr>
<td>Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control</td>
</tr>
<tr>
<td>Optimale Steuerung und Estimation / Optimal Control and Estimation</td>
</tr>
<tr>
<td>Optimierung / Optimization</td>
</tr>
<tr>
<td>Partikelsimulationsmethoden / Particle Simulation Methods</td>
</tr>
<tr>
<td>Rennautoregelung – Laboratory / Race Car Control Laboratory</td>
</tr>
<tr>
<td>Systemtheorie und Regelungstechnik II / Systems theory and automatic control II</td>
</tr>
<tr>
<td>VLSI Systementwurf / VLSI System Design</td>
</tr>
</tbody>
</table>

Concentration–Area Microsystems Engineering – Life sciences: Biomedical engineering | 205215

<table>
<thead>
<tr>
<th>Oberflächenanalyse / Surface Analysis</th>
<th>205215</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ausgewählte Problemstellung in Biosignalverarbeitung / Selected Problems in Biosignal Processing</td>
<td>207217</td>
</tr>
<tr>
<td>Bioaktive Polymeroberflächen / Bioactive Polymer Surfaces</td>
<td>209219</td>
</tr>
<tr>
<td>Bioaktive Polymeroberflächen mit Seminar / Bioactive Polymer Surfaces with seminar</td>
<td>211221</td>
</tr>
<tr>
<td>Biomedizinische Messtechnik I / Biomedical Instrumentation I</td>
<td>214224</td>
</tr>
<tr>
<td>Biomedizinische Messtechnik II / Biomedical Instrumentation II</td>
<td>217227</td>
</tr>
<tr>
<td>Biomedizinische Messtechnik - Laboratory / Biomedical Instrumentation - Laboratory</td>
<td>220230</td>
</tr>
<tr>
<td>BioMST 1 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 1 – Biotechnological Tasks for Microsystems Technology</td>
<td>222232</td>
</tr>
<tr>
<td>BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 2 – Biotechnological Tasks for Microsystems Technology</td>
<td>225235</td>
</tr>
<tr>
<td>Biophysik der Zelle / Biophysics of the cell</td>
<td>228238</td>
</tr>
<tr>
<td>DNA Analytik / DNA Analysis</td>
<td>231241</td>
</tr>
<tr>
<td>Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology</td>
<td>233243</td>
</tr>
<tr>
<td>Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems</td>
<td>235245</td>
</tr>
<tr>
<td>Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation</td>
<td>237247</td>
</tr>
<tr>
<td>Mikrobiologische Grundlagen für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems</td>
<td>239249</td>
</tr>
<tr>
<td>Mikrosytemtechnik in der Medizin / Microsystems technology in Medicine</td>
<td>241251</td>
</tr>
<tr>
<td>Nanobiotechnologie / Nanobiotechnology</td>
<td>243253</td>
</tr>
<tr>
<td>Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in Applications: Environmental Aspects and Nanotoxicity</td>
<td>245255</td>
</tr>
<tr>
<td>Neurophysiologie – Laboratory / Neurophysiology - Laboratory</td>
<td>247257</td>
</tr>
<tr>
<td>Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Neuroprothetik / Neuroprosthetics ................................................................. 249259</td>
<td></td>
</tr>
<tr>
<td>Neuwissenschaften für Ingenieure / Neuroscience for Engineers .......................... 252262</td>
<td></td>
</tr>
<tr>
<td>Oberflächenanalyse – Laboratory / Surface Analysis Laboratory ............................ 254264</td>
<td></td>
</tr>
<tr>
<td>Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals ................................................................. 256266</td>
<td></td>
</tr>
<tr>
<td>Technologien der Implantatfertigung / Implant Manufacturing Technologies .............. 259269</td>
<td></td>
</tr>
<tr>
<td>Technologien der Implantatfertigung – Laboratory / Implant Manufacturing Technologies - Laboratory ................................................................. 262272</td>
<td></td>
</tr>
<tr>
<td>Polymerchemie für Ingenieure / Polymer Chemistry for Engineers .......................... 264274</td>
<td></td>
</tr>
<tr>
<td>Concentration-Area Microsystems Engineering – Life sciences: Lab-on-a-chip ................ 266276</td>
<td></td>
</tr>
<tr>
<td>Biobrennstoffzelle und Bioelektrochemische Systeme / Biofuel Cells and Bioelectrochemical Systems ................................................................. 266276</td>
<td></td>
</tr>
<tr>
<td>Biochiptechnologien / Biochip Technologies .......................................................... 269279</td>
<td></td>
</tr>
<tr>
<td>BioMEMS ................................................................................................................. 271281</td>
<td></td>
</tr>
<tr>
<td>Biotechnologie für Ingenieure I: Einführung, Molekular- und Mikrobiologie (früher: BioMST 1 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik) / Biotechnology for Engineers I: Introduction, Molecular- and Microbiology (former: BioMST 1 – Biotechnological Tasks for Microsystems Technology) ................................................................. 273283</td>
<td></td>
</tr>
<tr>
<td>Biotechnologie II für Ingenieure: Bioprozesstechnik, Lebensmittelanalytik und in-vitro Diagnostik (früher: BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / Biotechnology for Engineers II: Bioprocess engineering, food analysis and in-vitro diagnostics (former: BioMST 2 – Biotechnological Tasks for Microsystems Technology) ................................................................. 276286</td>
<td></td>
</tr>
<tr>
<td>DNA Analytik / DNA Analysis .................................................................................. 279289</td>
<td></td>
</tr>
<tr>
<td>Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems ........ 281291</td>
<td></td>
</tr>
<tr>
<td>Mikrobiologische Grundlagen für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems ................................................... 283293</td>
<td></td>
</tr>
<tr>
<td>Mikrofluidik II: Mikrofluidische Plattformen / Microfluidics II: Platforms .................. 285295</td>
<td></td>
</tr>
<tr>
<td>Concentration-Area Microsystems Engineering – Materials ........................................ 288298</td>
<td></td>
</tr>
<tr>
<td>Analyse- und Messmethoden für Dünnschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies ................................................... 288298</td>
<td></td>
</tr>
<tr>
<td>Bioaktive Polymeroberflächen / Bioactive Polymer Surfaces ....................................... 290300</td>
<td></td>
</tr>
<tr>
<td>Bioaktive Polymeroberflächen mit Seminar / Bioactive Polymer Surfaces with seminar ................................................................. 292302</td>
<td></td>
</tr>
<tr>
<td>Bioinspirierte Funktionsmaterialien / Bioinspired functional materials ....................... 294304</td>
<td></td>
</tr>
<tr>
<td>Elektrochemische Energieanwendungen / Electrochemical energy applications ............ 298308</td>
<td></td>
</tr>
<tr>
<td>Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers ................................................................. 300310</td>
<td></td>
</tr>
<tr>
<td>Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology ......................... 302312</td>
<td></td>
</tr>
<tr>
<td>Halbleitertechnologie / Semiconductor Technology and Devices ................................ 304314</td>
<td></td>
</tr>
<tr>
<td>Keramiktechnologie in der Mikrotechnik / Ceramic technology in microsystems ........... 306316</td>
<td></td>
</tr>
<tr>
<td>Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems .......... 308318</td>
<td></td>
</tr>
<tr>
<td>Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure ................................................................. 310320</td>
<td></td>
</tr>
</tbody>
</table>
Kontinuumsmechanik I / Continuum mechanics I ........................................ 312322
Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises .... 314324
Kontinuumsmechanik II / Continuum mechanics II .................................... 316326
Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises .. 318328
Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms ........................................ 320330
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components . 322332
Nanomaterialien / Nanomaterials .................................................................. 324334
Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in Applications: Environmental Aspects and Nanotoxicity .................................. 326336
Nano – Laboratory / Nano - Laboratory ....................................................... 328338
Nanotechnologie / Nanotechnology .............................................................. 330340
Netzfreie Methoden in technischen Anwendungen / Particle Methods in Engineering .......................................................... 332342
Optische Materialien / Optical Materials ...................................................... 334344
Polymere in der Membrantechnik / Polymers in Membrane Technology ....... 336346
Polymerchemie für Ingenieure / Polymer Chemistry for Engineers .............. 338348
Quantenmechanik für Ingenieure / Quantum mechanics for engineers ......... 340350
Siliziumbasierte Neurosonden / Silicon-based Neural Technology .............. 342352
Techniken zur Oberflächenmodifizierung / Surface Coating Techniques ....... 344354
Teststrukturen und Methoden für ICs and MEMS / Test Structures and Methods for ICs and MEMS .......................................................... 346356
Verbindungshalbleiter / Compound semiconductor devices ........................ 349359
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld .... 351361
Werkstoffdynamik / Dynamics of Materials ................................................. 353363
Concentration-Area Microsystems Engineering – MEMS processing .......... 356366
Oberflächenanalyse / Surface Analysis ......................................................... 356366
BioMEMS ................................................................................................... 358368
CMOS-Integrierte Mikrosysteme / CMOS-Integrated Microsystems .......... 360370
Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies ...................................................... 362372
Fortgeschrittene Aufbau- und Verbindungstechnik / Advanced Assembly and Packaging Technology .......................................................... 364374
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology .......... 366376
Lithographie für Microsystems Engineers/ Litography for Microsystems Engineers .. 368378
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components . 370380
Mold Flow Simulation für Replikationsprozesse / Mold Flow Simulation for Replication Processes .......................................................... 372382
Nanotechnologie / Nanotechnology ............................................................. 374384
Oberflächenanalyse – Laboratory / Surface Analysis Laboratory ................. 376386
Optimierung von Fertigungsverfahren / Advanced engineering .................. 378388
Siliziumbasierte Neurosonden / Silicon-based Neural Technology .............. 380390
### Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content

<table>
<thead>
<tr>
<th>Modul / Seminar / Modulhandbuch M.Sc. Mikrosystemtechnik</th>
<th>Seite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teststrukturen und Methoden für ICs und MEMS / Test Structures and Methods for ICs and MEMS</td>
<td>383399</td>
</tr>
<tr>
<td>Concentration-Area Microsystems Engineering – Photonics</td>
<td>386396</td>
</tr>
<tr>
<td>Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics</td>
<td>386396</td>
</tr>
<tr>
<td>Optik-Laboratory Grundlagen / Basic Optics Laboratory</td>
<td>389399</td>
</tr>
<tr>
<td>Optik-Laboratory Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory</td>
<td>392402</td>
</tr>
<tr>
<td>Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures</td>
<td>396406</td>
</tr>
<tr>
<td>Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking</td>
<td>399409</td>
</tr>
<tr>
<td>Optische Materialien / Optical Materials</td>
<td>402412</td>
</tr>
<tr>
<td>Optische MEMS / Optical MEMS</td>
<td>404414</td>
</tr>
<tr>
<td>Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques</td>
<td>407417</td>
</tr>
<tr>
<td>Optische Mikrosensoren / Optical Micro-Sensors</td>
<td>409419</td>
</tr>
<tr>
<td>Photonische Mikroskopie / Photonic Microscopy</td>
<td>411421</td>
</tr>
<tr>
<td>Spektroskopische Methoden / Spectroscopic Methods</td>
<td>414424</td>
</tr>
<tr>
<td>Wellenoptik / Wave optics</td>
<td>416426</td>
</tr>
<tr>
<td>Concentration-Area Microsystems Engineering – Sensors and actuators</td>
<td>420430</td>
</tr>
<tr>
<td>Analyse- und Messmethoden für Dünnsschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies</td>
<td>420430</td>
</tr>
<tr>
<td>Bionische Sensoren / Bionic Sensors</td>
<td>422432</td>
</tr>
<tr>
<td>Bionische Sensoren - Laboratory / Bionic Sensors - Laboratory</td>
<td>424434</td>
</tr>
<tr>
<td>CMOS-Integrierte Mikrosysteme / CMOS-Integrated Microsystems</td>
<td>426436</td>
</tr>
<tr>
<td>Drahtlose Sensornetze / Wireless Sensor Networks</td>
<td>428438</td>
</tr>
<tr>
<td>Drahtlose Sensorsysteme / Wireless Sensor Systems</td>
<td>431441</td>
</tr>
<tr>
<td>Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers</td>
<td>433443</td>
</tr>
<tr>
<td>Energiegewinnung / Energy Harvesting</td>
<td>435445</td>
</tr>
<tr>
<td>Flugregelung Laboratory / Flight Control Laboratory</td>
<td>437447</td>
</tr>
<tr>
<td>Gassensorik / Gas Sensors</td>
<td>440450</td>
</tr>
<tr>
<td>Mikroakustik / Microacoustics</td>
<td>442452</td>
</tr>
<tr>
<td>Mikroakustik - Seminar / Microacoustics - Seminar</td>
<td>444454</td>
</tr>
<tr>
<td>Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control</td>
<td>446456</td>
</tr>
<tr>
<td>Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures</td>
<td>449459</td>
</tr>
<tr>
<td>Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking</td>
<td>452462</td>
</tr>
<tr>
<td>Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques</td>
<td>455465</td>
</tr>
<tr>
<td>Optische Mikrosensoren / Optical Micro-Sensors</td>
<td>457467</td>
</tr>
<tr>
<td>Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers</td>
<td>459469</td>
</tr>
<tr>
<td>Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II</td>
<td>461471</td>
</tr>
<tr>
<td>Piezoelektrische und dielektrische Wandler / Piezoelectric and dielectric transducers</td>
<td>464474</td>
</tr>
<tr>
<td>Quantenmechanik für Ingenieure / Quantum mechanics for engineers</td>
<td>467477</td>
</tr>
<tr>
<td>Rennautoregelung – Laboratory / Race Car Control Laboratory</td>
<td>469479</td>
</tr>
<tr>
<td>Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators</td>
<td>472482</td>
</tr>
<tr>
<td>Spektroskopische Methoden / Spectroscopic Methods</td>
<td>474484</td>
</tr>
<tr>
<td>Thermoelektrik / Thermoelectric</td>
<td>476486</td>
</tr>
<tr>
<td>Concentration-Area Microsystems Engineering – Personal profile</td>
<td>478488</td>
</tr>
<tr>
<td>Analyse- und Messmethoden für Dünnschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies</td>
<td>478488</td>
</tr>
<tr>
<td>Oberflächenanalyse / Surface Analysis</td>
<td>480490</td>
</tr>
<tr>
<td>Ausgewählte Problemstellung in Biosignalverarbeitung / Selected Problems in Biosignal Processing</td>
<td>482492</td>
</tr>
<tr>
<td>Bauelemente und Schaltungen der Leistungselektronik / Power Electronic Circuits and Devices</td>
<td>484494</td>
</tr>
<tr>
<td>Bioaktive Polymeroberflächen / Bioactive Polymer Surfaces</td>
<td>487497</td>
</tr>
<tr>
<td>Bioaktive Polymeroberflächen mit Seminar / Bioactive Polymer Surfaces with seminar</td>
<td>489499</td>
</tr>
<tr>
<td>Biobrennstoffzelle und Bioelektrochemische Systeme / Biofuel Cells and Bioelectrochemical Systems</td>
<td>491501</td>
</tr>
<tr>
<td>Biochiptechnologien / Biochip Technologies</td>
<td>494504</td>
</tr>
<tr>
<td>Biomedizinische Messtechnik I / Biomedical Instrumentation I</td>
<td>496506</td>
</tr>
<tr>
<td>Biomedizinische Messtechnik II / Biomedical Instrumentation II</td>
<td>499509</td>
</tr>
<tr>
<td>Biomedizinische Messtechnik - Laboratory / Biomedical Instrumentation - Laboratory</td>
<td>502512</td>
</tr>
<tr>
<td>BioMEMS</td>
<td>504514</td>
</tr>
<tr>
<td>BioMST 1 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 1 – Biotechnological Tasks for Microsystems Technology</td>
<td>506516</td>
</tr>
<tr>
<td>BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 2 – Biotechnological Tasks for Microsystems Technology</td>
<td>510520</td>
</tr>
<tr>
<td>Bionische Sensoren / Bionic Sensors</td>
<td>513523</td>
</tr>
<tr>
<td>Bionische Sensoren - Laboratory / Bionic Sensors - Laboratory</td>
<td>515525</td>
</tr>
<tr>
<td>Biophysik der Zelle / Biophysics of the cell</td>
<td>517527</td>
</tr>
<tr>
<td>CMOS-Integrierte Mikrosysteme / CMOS-Integrated Microsystems</td>
<td>520530</td>
</tr>
<tr>
<td>Computerunterstützte und mechanische Konstruktion / Computer-Aided and mechanical Design</td>
<td>522532</td>
</tr>
<tr>
<td>DNA Analytik / DNA Analysis</td>
<td>524534</td>
</tr>
<tr>
<td>Drahtlose Sensornetze / Wireless Sensor Networks</td>
<td>526536</td>
</tr>
<tr>
<td>Drahtlose Sensorsysteme / Wireless Sensor Systems</td>
<td>529539</td>
</tr>
<tr>
<td>Eingebettete Regelungssysteme Projekt / Embedded Control Project</td>
<td>531541</td>
</tr>
<tr>
<td>Elektrochemische Energieanwendungen / Electrochemical energy applications</td>
<td>533543</td>
</tr>
<tr>
<td>Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies ..........................................................</td>
<td>535545</td>
</tr>
<tr>
<td>Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers ..........................................................</td>
<td>537547</td>
</tr>
<tr>
<td>Energiegewinnung / Energy Harvesting ..........................................................</td>
<td>539549</td>
</tr>
<tr>
<td>Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells ..........................................................</td>
<td>541551</td>
</tr>
<tr>
<td>Energiewende / Energy Transition ..........................................................</td>
<td>543553</td>
</tr>
<tr>
<td>Entwurf Analog CMOS Schaltungen / Analog CMOS Circuit Design ..........................................................</td>
<td>545555</td>
</tr>
<tr>
<td>Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design ..........................................................</td>
<td>549559</td>
</tr>
<tr>
<td>Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation ..........................................................</td>
<td>551561</td>
</tr>
<tr>
<td>Etische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology ..........................................................</td>
<td>553563</td>
</tr>
<tr>
<td>Flugregelung Laboratory / Flight Control Laboratory ..........................................................</td>
<td>555565</td>
</tr>
<tr>
<td>Fortgeschrittene Aufbau- und Verbindungstechnik / Advanced Assembly and Packaging Technology ..........................................................</td>
<td>558568</td>
</tr>
<tr>
<td>Fortgeschrittene Eingebettete Systeme Laboratory / Advanced Embedded Systems Laboratory ..........................................................</td>
<td>560570</td>
</tr>
<tr>
<td>Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology ..........................................................</td>
<td>562572</td>
</tr>
<tr>
<td>Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics ..........................................................</td>
<td>564574</td>
</tr>
<tr>
<td>Fortgeschriebenes Praktikum für Mikrocontroller / Advanced Laboratory in Microcontroller ..........................................................</td>
<td>567577</td>
</tr>
<tr>
<td>Gassensorik / Gas Sensors ..........................................................</td>
<td>569579</td>
</tr>
<tr>
<td>Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems ..........................................................</td>
<td>571581</td>
</tr>
<tr>
<td>Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation ..........................................................</td>
<td>573583</td>
</tr>
<tr>
<td>Halbleitertechnologie / Semiconductor Technology and Devices ..........................................................</td>
<td>575585</td>
</tr>
<tr>
<td>Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method ..........................................................</td>
<td>577587</td>
</tr>
<tr>
<td>Innovationsmanagement - der Unterschied zwischen Spotify und Aldi / Innovation Management - how Spotify differs from Aldi ..........................................................</td>
<td>579589</td>
</tr>
<tr>
<td>Keramiktechnologie in der Mikrotechnik / Ceramic technology in microsystems ..........................................................</td>
<td>582592</td>
</tr>
<tr>
<td>Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems ..........................................................</td>
<td>584594</td>
</tr>
<tr>
<td>Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure ..........................................................</td>
<td>586596</td>
</tr>
<tr>
<td>Kontinuumsmechanik I / Continuum mechanics I ..........................................................</td>
<td>588598</td>
</tr>
<tr>
<td>Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises ..........................................................</td>
<td>590600</td>
</tr>
<tr>
<td>Kontinuumsmechanik II / Continuum mechanics II ..........................................................</td>
<td>592602</td>
</tr>
<tr>
<td>Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises ..........................................................</td>
<td>594604</td>
</tr>
<tr>
<td>Lattice Gas Methoden / Lattice Gas Methods ..........................................................</td>
<td>596606</td>
</tr>
<tr>
<td>Lithographie für Microsystems Engineers/ Lithography for Microsystems Engineers ..........................................................</td>
<td>599609</td>
</tr>
<tr>
<td>Magnetische Mikrosysteme / Magnetic Microsystems ..........................................................</td>
<td>601611</td>
</tr>
<tr>
<td>Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms ..........................................................</td>
<td>604614</td>
</tr>
<tr>
<td>Mikroakustik / Microacoustics ..........................................................</td>
<td>606616</td>
</tr>
<tr>
<td>Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Mikroakustik - Seminar / Microacoustics - Seminar ..........................................................</td>
<td>608618</td>
</tr>
<tr>
<td>Mikrobiologische Grundlagen für bioanalytische Systeme / Basics in Molecular Biology for</td>
<td>610620</td>
</tr>
<tr>
<td>Bioanalytical Systems .................................................................</td>
<td>610620</td>
</tr>
<tr>
<td>Mikrofluidik II: Mikrofluidische Plattformen / Microfluidics II: Platforms ..................</td>
<td>612622</td>
</tr>
<tr>
<td>Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components ........</td>
<td>615625</td>
</tr>
<tr>
<td>Mikrosystemtechnik in der Medizin / Microsystems technology in Medicine ..................</td>
<td>618628</td>
</tr>
<tr>
<td>Modellbildung und Systemidentifikation / Modelling and System Identification ............</td>
<td>620630</td>
</tr>
<tr>
<td>Mold Flow Simulation für Replikationsprozesse / Mold Flow Simulation for Replication</td>
<td>622632</td>
</tr>
<tr>
<td>Processes .................................................................</td>
<td>622632</td>
</tr>
<tr>
<td>Nanobiotechnologie / Nanobiotechnology .........................................................</td>
<td>624634</td>
</tr>
<tr>
<td>Nanomaterialien / Nanomaterials .............................................................................</td>
<td>626636</td>
</tr>
<tr>
<td>Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in</td>
<td>628638</td>
</tr>
<tr>
<td>Applications: Environmental Aspects and Nanotoxicity .........................................</td>
<td>628638</td>
</tr>
<tr>
<td>Nano – Laboratory / Nano - Laboratory .........................................................</td>
<td>630640</td>
</tr>
<tr>
<td>Nanotechnologie / Nanotechnology ......................................................................</td>
<td>632642</td>
</tr>
<tr>
<td>Neurophysiologie – Laboratory / Neurophysiology - Laboratory ..........................</td>
<td>634644</td>
</tr>
<tr>
<td>Neuroprothetik / Neuroprosthetics .....................................................................</td>
<td>636646</td>
</tr>
<tr>
<td>Neurowissenschaften für Ingenieure / Neuroscience for Engineers .......................</td>
<td>639649</td>
</tr>
<tr>
<td>Netzfreie Methoden in technischen Anwendungen / Particle Methods in Engineering ....</td>
<td>641651</td>
</tr>
<tr>
<td>Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control .......</td>
<td>643653</td>
</tr>
<tr>
<td>Numerische Optimale Steuerung mit Differentiell-Algebraischen Gleichungen / Numerical</td>
<td>646656</td>
</tr>
<tr>
<td>Optimal Control with Differential Algebraic Equations .....................................</td>
<td>646656</td>
</tr>
<tr>
<td>Numerische Optimierung / Numerical Optimization .............................................</td>
<td>650660</td>
</tr>
<tr>
<td>Numerische Optimierung Projekt / Numerical Optimization Project .......................</td>
<td>653663</td>
</tr>
<tr>
<td>Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project</td>
<td>655665</td>
</tr>
<tr>
<td>Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control ........</td>
<td>657667</td>
</tr>
<tr>
<td>Oberflächenanalyse – Laboratory / Surface Analysis Laboratory ................................</td>
<td>660670</td>
</tr>
<tr>
<td>Optik-Laboratory Grundlagen / Basic Optics Laboratory .....................................</td>
<td>662672</td>
</tr>
<tr>
<td>Optik-Laboratory Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory</td>
<td>665675</td>
</tr>
<tr>
<td>Optimale Steuerung und Estimation / Optimal Control and Estimation ..................</td>
<td>669679</td>
</tr>
<tr>
<td>Optimization/Optimierung .............................................................................</td>
<td>672682</td>
</tr>
<tr>
<td>Optimierung von Fertigungsverfahren / Advanced engineering ................................</td>
<td>674684</td>
</tr>
<tr>
<td>Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro</td>
<td>676686</td>
</tr>
<tr>
<td>and Nano Structures .................................................................................</td>
<td>676686</td>
</tr>
<tr>
<td>Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking ........</td>
<td>679689</td>
</tr>
<tr>
<td>Optische Materialien / Optical Materials .......................................................</td>
<td>682692</td>
</tr>
<tr>
<td>Optische MEMS / Optical MEMS ..................................................................</td>
<td>685695</td>
</tr>
<tr>
<td>Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical ....</td>
<td>688698</td>
</tr>
<tr>
<td>measurement techniques .............................................................................</td>
<td>688698</td>
</tr>
<tr>
<td>Optische Mikrosensoren / Optical Micro-Sensors ............................................</td>
<td>690700</td>
</tr>
<tr>
<td>Modulhandbuch M.Sc. Mikrosystemtechnik – Table of content</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Partikelsimulationsmethoden / Particle Simulation Methods .................................................. 692702</td>
<td></td>
</tr>
<tr>
<td>Photonische Mikroskopie / Photonic Microscopy ........................................................................ 695705</td>
<td></td>
</tr>
<tr>
<td>Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers ................................................................. 698708</td>
<td></td>
</tr>
<tr>
<td>Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II .................................................................. 700710</td>
<td></td>
</tr>
<tr>
<td>Piezoelektrische und dielektrische Wandler / Piezoelectric and dielectric transducers ................................................................. 703713</td>
<td></td>
</tr>
<tr>
<td>Polymere in der Membrantechnik / Polymers in Membrane Technology ........................................... 706716</td>
<td></td>
</tr>
<tr>
<td>Projektmanagement für Ingenieure / Project management for engineers ........................................... 708718</td>
<td></td>
</tr>
<tr>
<td>Quantenmechanik für Ingenieure / Quantum mechanics for engineers ............................................. 710720</td>
<td></td>
</tr>
<tr>
<td>Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers .................................... 712722</td>
<td></td>
</tr>
<tr>
<td>Rennautoregelung – Laboratory / Race Car Control Laboratory ....................................................... 714724</td>
<td></td>
</tr>
<tr>
<td>RF- und Mikrowellen Design Kurs / RF- and Microwave Design Course ........................................ 717727</td>
<td></td>
</tr>
<tr>
<td>RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits ................. 720730</td>
<td></td>
</tr>
<tr>
<td>RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems .............. 723733</td>
<td></td>
</tr>
<tr>
<td>Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators ........................ 726736</td>
<td></td>
</tr>
<tr>
<td>Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals .................................................. 728738</td>
<td></td>
</tr>
<tr>
<td>Siliziumbasierte Neurosonden / Silicon-based Neural Technology .................................................. 731741</td>
<td></td>
</tr>
<tr>
<td>Spektroskopische Methoden / Spectroscopic Methods .................................................................... 733743</td>
<td></td>
</tr>
<tr>
<td>Systemtheorie und Regelungstechnik II / Systems theory and automatic control II ............................. 735745</td>
<td></td>
</tr>
<tr>
<td>Techniken zur Oberflächenmodifizierung / Surface Coating Techniques .......................................... 738748</td>
<td></td>
</tr>
<tr>
<td>Technologien der Implantatfertigung / Implant Manufacturing Technologies .................................... 740750</td>
<td></td>
</tr>
<tr>
<td>Technologien der Implantatfertigung – Laboratory / Implant Manufacturing Technologies - Laboratory .................................................. 743753</td>
<td></td>
</tr>
<tr>
<td>Teststrukturen und Methoden für ICs und MEMS / Test Structures and Methods for ICs and MEMS ........................................................................ 745755</td>
<td></td>
</tr>
<tr>
<td>Thermoelektrik / Thermoelectric ........................................................................................................ 748758</td>
<td></td>
</tr>
<tr>
<td>Verbindungshalbleiter / Compound semiconductor devices .......................................................... 750760</td>
<td></td>
</tr>
<tr>
<td>VLSI Systementwurf / VLSI System Design ..................................................................................... 753763</td>
<td></td>
</tr>
<tr>
<td>Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld ....................................... 756766</td>
<td></td>
</tr>
<tr>
<td>Wellenoptik / Wave optics .................................................................................................................. 758768</td>
<td></td>
</tr>
<tr>
<td>Werkstoffdynamik / Dynamics of Materials ....................................................................................... 762772</td>
<td></td>
</tr>
<tr>
<td>Zuverlässigkeitsstechnik / Reliability Engineering .......................................................................... 765775</td>
<td></td>
</tr>
</tbody>
</table>

Publisher: ........................................................................................................................................ 768778
Mandatory Modules

In the program Master of Science in the subject Microsystems Engineering 14 mandatory modules with a total of 96 ECTS Points are offered. All 14 compulsory modules must be completed.
### Conclusion Module

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-8700-986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Examiners of the Department of Microsystems Engineering</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Department of Microsystems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Lehrveranstaltungstyp: Type of course</td>
<td>Written thesis</td>
</tr>
<tr>
<td>Sprache: Teaching language</td>
<td>German or English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory requirements</td>
<td>Admission for the thesis can be granted if at least 56 ECTS-credits have been acquired within the course program.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>30</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>900 hours</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>900 hours (900 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

### Lernziele / Learning target

The student shows with his/her Master thesis the ability to solve a given problem from microsystems engineering in a given time frame using scientific methodology. Skills and competencies obtained in the course program have been verifiably applied in accordance to the state of the art. The student has proven his/her ability to apply methods and knowledge as well as research and development competencies in the project, the scientific documentation and the oral presentation.

### Inhalte / Content

The Master thesis is an independent research project. It consists of a written documentation and a final presentation with discussion. The student works on a given topic for a given timeframe and has to deliver a scientific documentation.

### Zu erbringende Prüfungsleistung / Examination result

The Module consists of
- Written documentation of the thesis
- Oral presentation of the results of the thesis

The final module grade is calculated from the grade of the written thesis (4/5) plus the grade from the presentation of the thesis (1/5).

### Benotung / Grading

The final module grade is calculated from the grade of the written thesis (4/5) plus the grade from the presentation of the thesis (1/5).

### Gewichtung der Prüfungsleistung / Weight of examination result

Master of Science in Microsystems Engineering, academic regulations of 2009: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.
Assembly and packaging technologies

Number: 11LE50MO-7700/986

Responsible person: Prof. Dr. J. Wilde

Organisational unit: Chair for Assembly and Packaging Technology

Module Type: Mandatory Module

Module duration: 1 term

Connected events: Lecture and exercises

Language: English

Recommended preconditions:
- Basic knowledge about Materials Science (metals, ceramics and polymers)
- Mechanics (basic properties, stress, strain)
- Manufacturing technology

Recommended term of study: 2

ECTS-points: 5

Semester week hours: 2 lecture + 1 exercises

Regular cycle: only in the summer term

Workload: 150 hours (42 Hours Full-time attendance course of study + 108 Hours Self-study)

Usability of the module:
Mandatory Module for students of the study program:
- Master of Science in Embedded Systems Engineering
- Master of Science in Microsystems Engineering
- Master of Science in Mikrosystemtechnik

Learning target:
It is the principal learning goal to understand how modern electronics hardware is generated with industrial processes, especially in the field of microsystems. The focus lies on the standard technologies for interconnection, assembly and housing. Furthermore it is the aim to know the concepts how to design and optimise assembly; packaging for electronic hardware with respect to functionality, reliability, stress and environmental aspects. Also application competences in theses fields will be acquired.

Content of the lecture:
Assembly and packaging comprises a complex technology which aims at the fabrication of electronic hardware. This technology is mainly based on Materials Science and Engineering, Mechanical and Electrical Engineering. The target is to connect a functional element to an
application and at the same time to protect it from the environment. Fabrication technologies comprise assembly, joining and interconnection, while the main constructional elements are substrates, housings or packages. For all of these present days’ state of the art is presented and the fundamental requirements are demonstrated. So the students will get an overview of the basic manufacturing operations and the required materials in order to integrate electronic hardware. Besides, it is indispensable that knowledge about modern techniques for design optimisation will be taught. Electronic systems must fulfil specifications concerning integration density, high frequency behaviour, thermal management, thermal-mechanical behaviour and lifetime. To that purpose, the basic techniques for performance and reliability optimization will be regarded. In this way, it is desired that the students will become capable of finding own solutions in the field of assembly and packaging of microsystems.

The course comprises the following s
- Housing and packaging technologies - Hermetic and plastic packaging, wafer-level packaging
- Substrates - Printed circuit boards, multi-chip-modules, moulded interconnect devices
- Assembly technologies - Surface mount technology, adhesive bonding
- Interconnection technology - Wire bonding, flip-chip-bonding
- Electromagnetic compatibility EMC - Integrity and speed of electrical signals and equivalent circuits
- Thermal management - Temperature problems and cooling techniques
- Mechanical optimization - Temperature problems and cooling techniques

### Inhalte Übung / Content of the exercises

The exercises are designed to deepen the teaching contents of the lecture. Students will be placed in particular in a position to create key concepts under consideration of material and production aspects in specific assembly and packaging technology tasks. Furthermore, the goal is that the students are able to analyze assembly and packaging technology concepts regarding quantitative performance and optimize. These include for example, signal propagation time, thermal performance and durability.

The exercises are passed if 50% of the maximum points are reached from the exercises.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

An English manuscript will be made available in printed and in electronic form. Sources of information and references for the various fields are given in the manuscript.
# Biomedical Microsystems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-7900</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | • Basic knowledge in mathematics and natural sciences,  
• Fundamental knowledge in processes and components of microsystems engineering |
| Empfohlenes Fachsemester: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 5 |
| SWS: Semester week hours | 2 lecture + 2 exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 150 hours (56 hours Full-time attendance course of study + 94 hours Self-study) |

---

**Verwendbarkeit der Veranstaltung / Usability of the module**

Mandatory Module for students of the study program
- Master of Science in Embedded Systems Engineering
- Master of Science in Microsystems Engineering

**Lernziele / Learning target**

Objective of the module is to teach the technological requirements of microsystems in biomedical applications. Aspects of material science, standards and directives as well as technological opportunities will be evaluated. Examples from a variety of applications of approved medical devices and research prototypes in clinical trials will be presented and assessed.

The module teaches the students which particular requirements have to be taken into account if microsystems should be used as a medical device. It will give a broad overview of the possible extent of microsystems applications in medical devices. The accompanying exercises supplement the lecture with respect to further applications. They guide the students towards independent learning whereas literature research, application and transfer of already acquired technological knowledge strengthen the engineering skills for research and development tasks in new application fields.
### Inhalte Vorlesung / Content of the lecture

The course presents exemplary applications of microsystems in biomedical engineering, discusses challenges and illustrates solutions to meet the requirements of biocompatibility, biostability and reliability in clinical applications. In detail, the following topic will be covered:

- Introduction to Biomedical Microdevices
- Medical Devices: Legal Framework and Classification
- Glaucoma Monitoring Implant
- Neural Implants to Restore Vision
- Neural Implants to Record from the Brain
- Sensors in Cardiac Pacemakers
- Imaging Pills
- Spectroscopic Billirubin Measurement
- Trends for Intelligent Endoprostheses
- Stability and Functionality Implantable MEMS
- Packaging and Housing Concepts
- Data and Energy Transmission in (Micro-)Implants

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

### Inhalte Übung / Content of the exercises

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature
Actual copies of the slides will be delivered accompanying to the lectures. Literature:

Dynamics of MEMS

Nummer: 11LE50MO-7200

Modulverantwortlicher: N.N.

Einrichtung: Chair for Simulation

Modultyp: Mandatory Module

Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Basic knowledge in experimental physics and differential equations

Empfohlenes Fachsemester: 2

ECTS-Punkte: 5

SWS: 2 lecture + 1 exercise

Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 150 hours (42 hours Full-time attendance course of study + 108 hours Self-study)

Verwendbarkeit der Veranstaltung

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Personal Profile

Lernziele

The ultimate learning goal of the module is to enable students to study the electromechanics of microsystems, using Lagrangian dynamics. After the revision of kinematics, based on vector analysis, and of "classical" Newtonian mechanics, the students are introduced the more general variational dynamics based on Lagrange's equations and Hamilton's principle. Applications are besides mechanical particulate systems, mechanical systems containing extended bodies, electrical networks and electromechanical systems. Finally, students are required to apply these concepts for the solution of the most relevant dynamic phenomena in microsystems engineering.
### Inhalte Vorlesung / Content of the lecture

The electromechanics of MEMS, in a dynamic setting, is presented based on the method of Lagrange. You will learn the following:

- Kinematics of particles
- Simple Newtonian mechanics, and the jump to a Lagrangian formulation
- Extended masses
- Electrical Lagrangians
- Electromechanical Lagrangians
- Continuous systems (beams).

The lecturer will also weave in numerous examples from everyday MEMS practise, typically as found in movable micro-optical systems, micro-actuators, and inertial sensors.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

We focus on the book by James H. Williams: Fundamentals of Applied Dynamics.
Modul / Module

Micro-actuators

Nummer: Number

11LE50MO-7300

Modulverantwortlicher: Responsible person
Prof. Dr. U. Wallrabe

Einrichtung: Organisational unit
Chair for Microactuators

Modultyp: Module Type
Mandatory Module

Moduldauer Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes

Empfohlenes Fachsemester:: Recommended term of study
2

ECTS-Punkte: ECTS-points
5

SWS: Semester week hours
2 lecture + 1 exercises

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
150 hours
(42 hours Full-time attendance course of study + 108 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Mandatory Module for students of the study program
• Master of Science in Microsystems Engineering

Lernziele / Learning target
The students should get acquainted with the most common actuation principles. This includes the basic knowledge of the physical principles and equations, the integration into micro technology and the specific fabrication processes and applications. Furthermore the critical examination of the different actuation principles is also encouraged. After the course, the students should be familiar with the advantages and disadvantages of the different actuation principles and be able to choose the right mechanism for a novel application with respect to the typical parameters like force and displacement, but also complexity of the fabrication process, ease of integration and reliability.

Inhalte Vorlesung / Content of the lecture
The lecture starts off with a short recapitulation of the principles of mechanical engineering that are especially relevant for actuators: Newtonian mechanics, force, impulse, energy, torque, friction, forced oscillation with and without damping, resonance, waves and the wave equation.
Then the actuation principles mentioned below are worked through. For each principle the specific basic physical equations are presented. Afterwards the integration of that principle
into micro technology and typical examples of scientific literature or commercial products are shown. The actuation principles are:

**Electrostatics**
First the plate capacitor with one direction of motion perpendicular to the plate is introduced. The special pull-in characteristic is derived. Then the direction of motion parallel to the plate is covered, which resembles a comb actuator leading to a linear or tilting motion, depending on the design of the actuator. Lastly rotating motors are covered.

**Electromagnetics**
The easiest actuator uses the Lorentz force. Here the possibility of using bi-stable and snap-action mechanisms arises. After the Lorentz-force actuators, magnetic reluctance actuators with the challenge of coil winding, the use of eddy currents and the assembly of small electromagnetic motors are discussed.

**Piezoelectricity**
Piezoelectric behavior is first introduced using the example of SiO$_2$, followed by PZT. Since piezo actuators are commonly obtained as modular parts, typical commercially available designs are presented and standard applications are discussed. As a special case, surface waves excited within a piezoelectric substrate are shown. The applications of these devices include RFID-tags and friction-controlled rotary motors.

**Shape Memory Metals**
The special behavior of NiTi is introduced concerning the aspect of shape memory and super elasticity. The method of shape settings is illustrated, followed by numerous examples, especially super elasticity used in medical engineering.

**Polymer actuators**
Less known for hydroactive polymers, polymer actuators are a common synonym for dielectric elastomer actuators. The importance of the choice of the actuator material and the influence of the material on percolation and the dielectric constant is exemplified. Typical challenges and applications for polymer actuators are identified.

**Hydrodynamic**
After a theoretical introduction to fluid dynamics, two types of turbines are presented: Firstly actual micro turbines, where the challenge of friction can be exemplified and secondly turbines in the millimeter range for surgical applications. This is followed by active multi-pathway valves and a short overview over micro pumps.

---

**Inhalte Übung / Content of the exercises**
During semester each student has to pass one short test of 45 min to be admitted to the final exam. In addition each student has to present an exercise solution on the black board once.

**Zu erbringende Prüfungsleistung / Examination result**
written or oral examination
<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the results of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
### Micro-electronics

<table>
<thead>
<tr>
<th>Modulnummer: Number</th>
<th>11LE50MO-7050/986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Y. Manoli</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fritz Huettinger Chair of Microelectronics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in electrical engineering and good knowledge in electronics, especially the topics covered in “Grundlagen der Elektronik” (Module of the study programme Bachelor of Science in Mikrosystemtechnik).</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>1</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lectures + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Embedded Systems Engineering
- Master of Science in Microsystems Engineering
- Master of Science in Mikrosystemtechnik

### Lernziele / Learning target

Having attended the module, the students will be able to understand and to design widely used basic analog integrated circuits like current mirrors and differential amplifiers. The students understand the physical principles and the use of MOS transistors in circuits and are able to build simple circuits. Furthermore, they will be able to analyze microelectronic systems on block and on transistor level.

### Inhalte Vorlesung / Content of the lecture

This course covers the fundamentals of microelectronics for analog circuits. It starts with a review of the CMOS process and the available components. Then, current sources, single stage amplifiers and differential amplifiers are discussed in time and frequency domain. The presentation of basic circuit concepts and their enhancements is completed with an introduction into analog circuit layout and a discussion of electronic noise in circuits. At last, applications of the presented circuits are shown, with a special focus on MEMS.
sensor readout.

List of contents:
1. Introduction and review of CMOS technology and available components
2. Small signal equivalent circuit
3. Current sources
4. Single stage amplifier and its frequency behaviour
5. Differential amplifiers
6. Noise in electronic circuits
7. Analog layout
8. MEMS Applications

Inhalte Übung / Content of the exercises
A weekly exercise is offered. Four short tests (quizzes) during the semester will be written at the beginning of the exercise class. Approximately 40 % of the maximum points have to be achieved in order to be allowed to write the final examination.

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Zu erbringende Studienleistung / Course Achievement
The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
- Allen, Holberg: CMOS Analog Circuit Design, Oxford University Press
- Sedra, Smith: Microelectronic Circuits, Oxford University Press
Modul / Module

Micro-fluidics

Nummer: Number 11LE50MO-7150/986

Modulverantwortlicher: Responsible person Prof. Dr. R. Zengerle

Einrichtung: Organisational unit Chair for MEMS Applications

Modultyp: Module Type Mandatory Module

Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Basic knowledge in physics

Empfohlenes Fachsemester: Recommended term of study 2

ECTS-Punkte: ECTS-points 5

SWS: Semester week hours 2 lectures + 2 exercises

Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

Lernziele / Learning target

Technically correct handling of very small amounts of liquid and gas is of central importance in all key areas of microsystems engineering such as Lab-on-a-Chip applications, InkJet technology and fuel cells. This lecture gives an overview on physical phenomena and presents the most important application examples of microfluidic systems.

The educational objective of the Microfluidics I lecture is to gain a general understanding regarding all basic microfluidic effects including fluid mechanics, fluid properties and both physical and chemical interaction at boundary layers. Participating students will learn to apply micro- and macrofluidic effects and phenomena to design new systems. This is achieved by introducing basic microfluidic elements that can be utilized as elementary units to create complex microfluidic devices.

Inhalte Vorlesung / Content of the lecture

The topics of this course are:
- Basic fluid properties
- Fluid dynamics including the Navier-Stokes-Equation
- Diffusion
• Surface tension
• Electrokinetics
• The design of microfluidic chips
• Basic fluidic elements

**Inhalte Übung / Content of the exercises**

The curriculum of practice serves to deepen the learning material and for introduction into independent calculation and design of microfluidic systems. The exercises have been passed if at least 50% of the exercise sheets have been prepared and submitted as well as if 50% of the practice sessions were attended. The grade is then calculated from the average of all points from all exercise sheets.

**Zu erbringende Prüfungsleistung / Examination result**

- Written or oral examination
- Graded exercises/practical exercises
The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Benotung / Grading**

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Gewichtung der Prüfungsleistung / Weight of examination result**

Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Nguyen, Wereley; Microfluidics, Artech House
- Geschke, Klank, Telleman; Microsystem Eng. of Lab-on-a-Chip Devices, Wiley-VCh, 2nd edition
- Bruus; Theoretical Microfluidics, Oxford Univ. Press
## Micro-mechanics

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-7100/986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Design of Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Recommended preconditions
Participants of this module should - ideally - have basic knowledge in engineering mechanics (statics), as well as basic mathematics (right triangle geometry, vector operations, basic calculus). A short introduction of statics was included in the pre-semester study packet distributed to incoming students, in order to balance the variable levels of knowledge usually present in an international master class. It is EXTREMELY IMPORTANT that students study this material BEFORE THE SEMESTER in order to be prepared when the lecture begins.

### Empfohlenes Recommended term of study

<table>
<thead>
<tr>
<th>Fachsemester: Recommended term of study</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lectures + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours</td>
</tr>
<tr>
<td></td>
<td>(64 hours Full-time attendance course of study + 86 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung Usability of the module

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile

### Lernziele Learning target

Micromechanics is one of the required courses for incoming students and focuses on the mechanics of materials, static loads, elastostatic deformation of beams and plates, torsion and energy methods for solving mechanical deformations. These topics are key to the design and testing of Micro-Electro-Mechanical Systems (MEMS). Therefore, an understanding of the mechanical properties of microstructures and analysis techniques is very important.
Elastomechanics is the main focus of this lecture. The student will learn about the basic elastomechanic theory and its application to the most relevant micromechanical design elements, such as bending and torsional beams, plates and columns. Composite structures and MEMS-related micromechanical effects are also presented. The following topics are part of this lecture:

### Hooke’s Law
- Generalized Hooke’s Law: Normal and Shear Stress/Strain Relations
- Relations between Material Property Parameters (Young’s Modulus, Shear Modulus, Poisson Ratio)
- Thermal Strain
- Special Case: Plane Stress

### Elastostatics
- Stress/Strain Tensors and Index Notation
- Differential Equations of Elastostatics
- Kinetic Equations and Strain Compatibility
- Load-Equivalent Stress Conventions (Average, Normal, Mohr, von Mises)
- Airy Stress Function and the Bipotential Equation
- St. Venant’s Theorem and Stress Concentrations

### Beam Bending
- The Beam Bending Line and Bernoulli’s Assumption
- Centroid and Area Moment of Inertia
- Bearings and Boundary Conditions, Static Determinacy
- Singularity Functions (Föppl Symbols) for Sectored Loading
- Principle of Superposition
- Beam Bending under Skew Loading
- Column Buckling
- Composite Beams

### Plate Bending
- Plates vs. Membranes
- Kirchoff Plate Theory
- Two-Axis Bending
- Plate Bending Equations
- Boundary Conditions
- Square and Circular Plates

### Torsion
- St. Venant’s Theory of Torsion
- Torsional Warping Function
- Torsional Moment of Inertia
- Differential Equation of Torsion
- Composite Cross-Sectional Shapes, Tubes, Shells

### Energy Methods
- Work and Deformational Energy
- Castigliano’s Theorem
- Principle of Virtual Work
- Clapeyron’s Theorem
The module grade is calculated from the result of the final examination.

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering (PO 2012): The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
### Modul / Module

**Micro-optics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-7600/986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

### Lernziele / Learning target

Optics is the science and engineering of light and is one of the most important technical disciplines with wide-ranging applications in both basic science and in industrial application. Micro-optics is optics for microsystems, small-scale components and systems which bring light into MEMS. This course will introduce the physics of light, the concepts of optics and optical components and their use in a broad variety of microsystems.

The instructional aim of the course Micro-optics is the establishment of competence in basic optics, including optical components and systems, and generation of the ability to incorporate optical concepts into MEMS.

At the completion of the course, the successful student should possess:
- a basic understanding of electromagnetic radiation and its interaction with matter;
- the ability to analyze and understand the most important optical components and their functionality;
- expertise in the analysis of fundamental lens combinations;
- the ability to design and calculate the behavior of simple optical systems;
- an awareness of the most important fabrication and assembly processes used in optics;
  - the ability to understand and apply micro-optical components and concepts in microsystems.
Inhalte Vorlesung / Content of the lecture

This course covers the fundamentals of micro-optics with a focus on implementation and application in optical microsystems. Following an overview of the relevant basic mathematics and electromagnetics, we will consider optical phenomena including Gaussian optics, optical interfaces and materials. The core of the course consists of an in-depth presentation of reflective, geometric, diffractive and integrated optics. In each section, both the basic optical components as well as their application in microsystems are considered.

Table of contents:
1. Electromagnetic waves
2. Light waves & beams
3. Optical materials
4. Optical interfaces
5. Reflective optics
6. Refractive optics
7. Refractive components
8. Refractive systems
9. Diffractive optics
10. Diffractive components
11. Waveguide optics
12. Fiber optics
   • 13. Fabrication

Inhalte Übung / Content of the exercises

The curriculum of practice serves to deepen the learning material micro-optics. The exercises have been passed if at least 50% of the exercise sheets have been prepared and submitted as well as if 50% of the practice sessions were attended. The grade is then calculated from the average of all points from all exercise sheets.

Zu erbringende Prüfungsleistung / Examination result

• Written or oral examination
• Graded exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

English:
• H. Zappe: Fundamentals of Micro-optics
• E. Hecht: Optics
• R. Hunsperger: Integrated Optics
• B. Saleh & M. Teich: Fundamentals of Photonics
• S. Sinzinger & J. Jahns: Microoptics
• W. Smith: Modern Optical Engineering
• H. Zappe: Introduction to Semiconductor Integrated Optics
In German:
• E. Hecht: Optik
  • G. Litfin: Technische Optik in der Praxis
# MST Design Laboratory

## Teilmodul / Part Module

**MST Design Laboratory I**

**MST Design Laboratory II**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-7001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Woias, Dr. Greiner</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Design of Microsystems Chair of Simulation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Modulalter: Module duration</td>
<td>2 terms</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>1 and 2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory + 2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (60 Hours Full-time attendance course of study + 120 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile

## Lernziele / Learning target

In the first part of the module MST Design Laboratory I the students learn to experience and learn the process of product design, with the involvement of MEMS components. Teaching subject is the phase model of a product design process, with the stages (1) product planning (2) product concept (3) product design (4) product elaboration. The lab course will train these methods with a virtual product design. In the second part of the module MST Design Laboratory II the students learn how to practically build and test the virtual product idea that has been developed in the first part of the module.

## Inhalte Praktikum / Content of the laboratory
MST Design Laboratory I:
During the laboratory the students will be trained in appropriate tools that are required to perform a complete product design process with all its four phases. As an exemption, no CAD or basics of mathematical methods will be implemented. In the lab course, the students will form groups of typically 5 persons, that have, as a product design team, to find a product idea and make a virtual product design including a demonstration of its technical feasibility, the meeting of a given cost target and the presence of a - real - market for their idea.

MST Design Laboratory II:
In the lab course, the students will form groups of typically 5 persons, in an ideal way the same team that has already been formed during the MST Design Lab I. These groups will practically build the product idea developed during MST Design Lab I, including electronic design, software programming and mechanical machining.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Projects are presented in a poster or presentation session</td>
</tr>
<tr>
<td>- Graded protocols</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the results of the graded protocols.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
MST technologies and processes

**Nummer:** 11LE50MO-7250

**Modulverantwortlicher:** N.N.

**Einrichtung:** Chair for Process Technology

**Modultyp:** Mandatory Module

**Moduldauer:** 1 term

**Zugehörige Lehrveranstaltungen:** Lecture

**Sprache:** English

**Empfohlenes Fachsemester:** 1

**ECTS-Punkte:** 5

**SWS:** 4 lecture

**Angebotsfrequenz:** Only in the winter term

**Arbeitsaufwand:** 150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)

**Verwendbarkeit der Veranstaltung**

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Personal Profile

This module can be set as a prerequisite for the admission to study in a Master’s program.

**Lernziele**

It is the learning target that students will have a sound understanding of the fundamentals of MEMS technologies. They will know
- the physical and technological background of microsystems processing
- process flows for the fabrication of MEMS elements
- principals of material sciences (silicon and other semiconductors)
- principals of clean-room and vacuum technologies

Also the students will be able to apply this knowledge practically to own designs, and especially in the MST design laboratories.

**Inhalte Vorlesung**

- Connected events
- Language English
- 1 term
- 4 lecture
- Only in the winter term
- 150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)
The content of the course:

- overview of MEMS processing (silicon, polymers)
- mechanical, chemical and physical properties of silicon
- cleanrooms – layout, function and operational procedures
- lithographic methods: physical background, optical lithography, ebeam lithography, x-Ray lithography
- vacuum technology, thin film and etching processes: physical and chemical background, Oxidation, Doping, Implantation, Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Chemical etching processes. Plasma and reactive ion etching (RIE)
- surface and bulk micromachining (process chains)
- back end processing: wafer bonding, dicing
- assembly and packaging

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Probability and statistics

| Nummer: Number | 11LE50MO-6100 |
| Modulverantwortlicher: Responsible person | Prof. Dr. T. Stieglitz |
| Modultyp: Module Type | Mandatory Module |
| Zugehörige Lehrveranstaltungen: Connected events | Lecture and exercises |
| Empfohlene Voraussetzungen: Recommended preconditions | Basic knowledge in mathematics |
| Nummer: Number | 11LE50MO-6100 |
| Modulverantwortlicher: Responsible person | Prof. Dr. T. Stieglitz |
| Modultyp: Module Type | Mandatory Module |
| Zugehörige Lehrveranstaltungen: Connected events | Lecture and exercises |
| Empfohlene Voraussetzungen: Recommended preconditions | Basic knowledge in mathematics |

| Empfohlenes Fachsemester:: Recommended term of study | 1 |
| ECTS-Punkte:: ECTS-points | 5 |
| SWS: Semester week hours | 2 lectures + 2 exercises |
| Angebotsfrequenz:: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 150 hours (64 hours Full-time attendance course of study + 86 hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
- Master of Science in Mikrosystemtechnik
  - Personal Profile

This module can be given as a conditional course to Master students from the Embedded Systems Engineering or Computer Science programs.

Lernziele / Learning target

The overall aim of the module is that students will have insights into the field of probability and statistics. Complemented by many examples, the students learn to apply probability theory and statistics in order to analyze data. After the course The students will be able to assess and evaluate the results they obtained.

Inhalte Vorlesung / Content of the lecture

The overall aim of the module is that students will have insights into the field of probability and statistics. Complemented by many examples, the students learn to apply probability theory and statistics in order to analyze data. After the course The students will be able to assess and evaluate the results they obtained.
The topics of this course cover:
- Probability theory:
- Discrete random variables
- Continuous random variables
- Statistics:
- Parameter estimation
- Linear and nonlinear regression
- Statistical tests
- Random numbers and Monte-Carlo simulation
- Experimental design
- Statistical process control
- Time series analysis

Inhalte Übung / Content of the exercises

The exercises are considered passed if 50% of maximum points will be achieved from the
tests that are written in the exercises with prior notice.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the
written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- J. Honerkamp, Stochastic Dynamical Systems, VCH, Weinheim
• D. Stoyan, Stochastik für Ingenieure und Naturwissenschaftler, Akademie Verlag, 1993
• U. Krengel, Einführung in die Wahrscheinlichkeitstheorie und Statistik: Für Studium, Berufspraxis und Lehramt, Vieweg und Teubner 2005
# Sensors

**Modulhandbuch M.Sc. Mikrosystemtechnik – Sensors**

**Modul / Module**

**Sensors**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-7500/986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics, mathematics and materials</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Lecture + 1 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Mandatory Module for students of the study program
- Master of Science in Microsystems Engineering

**Lernziele / Learning target**

Participants should exhibit
- a comprehensive overview over all technical sensor types,
- their working principles,
- measurement ranges,
- accuracies,
- Their realization technologies.
- Thermodynamics and material based conversion principles for sensor functions.

Students should be enabled to select, apply, optimise, existing sensor types and establish sensor signal handling for a specific task. Furthermore, they should gain abilities to develop novel sensor types and technologies for their realization.
The Sensors lecture gives an overview about methods and technologies creating sensors and actuators focussing on micro-technology.

In the lecture, an introduction in basics of sensor principles is given starting with bionic principles, thermodynamics as sensor theory and also close insights into industrial sensors and production technologies are provided. Emphasis is laid on micro technological technologies and methods.

The lecture covers physical sensors as temperature, radiation, force, pressure and gear rate. Also magnetic sensors, optical sensors and position and angular arte sensors are presented. The very actual topics of chemo-, gas- and biosensors complete the lecture. Additionally electronic interfaces, linearization procedures and applications will be communicated.

Examples of university and industrial environment will be demonstrated and the problems occurring in real life discussed.

For each experiment there will be a short written test with a grade for the individual student (mean value of the three experiments contribute 30% to the overall grade). For each experiment there will be a judging about the work done during the lab course (mean value of the three experiments contribute 20% to the overall grade). For each protocol a grade is assigned to the student who is responsible for the protocol (50% of the overall grade).

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Signal Processing

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-7400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair of Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Mandatory Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzungen: Recommended preconditions
Mathematics [Complex numbers, Trigonometry, Calculus, Linear algebra, Circuit analysis (R, L, C), Differential equations]

### Empfohlenes Fachsemester: Recommended term of study
| 2 |

### ECTS-Punkte: ECTS-points
5

### SWS: Semester week hours
| 2 lecture + 1 exercises |

### Angebotsfrequenz: Regular cycle
Only in the summer term

### Arbeitsaufwand: Workload
150 hours (42 hours Full-time attendance course of study + 108 hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module
- Mandatory Module for students of the study program
  - Master of Science in Microsystems Engineering
- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Circuits and systems
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Circuits and systems
    - Personal Profile

### Lernziele / Learning target
With this module students will be able to mathematically model the propagation of signals in electronic systems, enabling them to optimize their design. In particular students will be able to design and test analog and digital filters.

### Inhalte Vorlesung / Content of the lecture
The purpose of the course is to teach students how to mathematically model the propagation of signals through electrical systems. The following topics will be covered in the
course:

Zu erbringende Prüfungsleistung / Examination result
Written or oral examination

Benotung / Grading
The module grade is calculated from the results of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
- Denbigh, Philip: System Analysis and Signal Processing
- Butz, Tilman: Fouriertransformation für Fußgänger
- Daniel Ch. von Grüningen: Digitale Signalverarbeitung, Fachbuchverlag Leipzig
- E. Schrüfer: Signalverarbeitung, Hanser Verlag
- R. Scheithauer: Signale und Systeme, Teubner Stuttgart
- Kammeyer, Kroschel: Digitale Signalverarbeitung
- Mertins: Signal Analysis
- Mitra: Digital Signal Processing
- Kay: Fundamentals of statistical signal processing & Modern spectral estimation
- Einführung in MATLAB, Skript zu den Übungen Signalverarbeitung SS2005
- Lectures script Signalverarbeitung SS2005
- Oppenheim, Schafer: Zeitdiskrete Signalverarbeitung
- Ingle, Proakis: Digital Signal Processing using MATLAB
Elective Modules Master of Science in Microsystems Engineering/ Microsystemtechnik Concentrations

The Elective Part is structured in 9 Concentration-Areas:
1. Circuits and systems
2. Design and simulation
3. Life sciences: Biomedical engineering
4. Life sciences: Lab-on-a-chip
5. Materials
6. MEMS Processing
7. Photonics
8. Sensors and actuators
9. Personal Profile

In the Master of Science in Microsystems Engineering a variety of Concentrations modules are offered in different Concentrations directions. In total Concentrations modules with a circumference of at least 24 ECTS points must be completed. Students must select 2 Concentration-directions and in each direction Concentrations modules with a minimum of 9 ECTS points must be completed.
Concentration-Area in Microsystems Engineering – Circuits and Systems

The Concentrations direction "Circuits and systems" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

<table>
<thead>
<tr>
<th>Module / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauelemente und Schaltungen der Leistungselektronik / Power Electronic Circuits and Devices</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-9010</th>
<th>Gültig ab: Valid from</th>
<th>01.04.2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Ambacher, PD Dr. Quay</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Compound Semiconductor Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 2 | ECTS-Punkte: ECTS-points | 5 |
| SWS: Semester week hours | 2 lectures + 2 exercises | Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 150 hours (56 hours Full-time attendance course of study + 94 hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering

Lernziele / Learning target

The students will be enabled to understand materials, concepts, functioning, and design of modern power devices, circuits, and converter systems suitable for microscopic and
macroscopic energy systems. This includes the understanding of hair cells and engine proteins as well as solar energy photovoltaic converters and engines in traffic. The basic concepts of power conversion (AC theory), of passive and active semiconductor devices, high-voltage operation, converter-, and control concepts, device protection, and aspects of system and power network theory are treated. The students will be competent to analyze, understand the fabrication, and design passive and active power devices such as MOSFET, Insulated Gate Bipolar IGBT, Junction FETs (JFET), thyristors, and circuits, full converter functions, integration, and analyze full system concepts. Circuits and system concepts for power conversion, such as half and full bridges, current controls, aspects high voltage operation, and design for robustness are presented, and several examples are discussed in detail.

**Inhalte Vorlesung / Content of the lecture**

The lecture deals with the fundamentals and concepts of power devices and circuits. It comprises three parts: fundamental power conversion-concepts with focus on DC-DC and – AC conversion, more complex power circuitry, and actual power conversion systems. At the interface of modern electronics, circuit design, and control theory, advanced analysis, fabrication, and characterization techniques are introduced in order to bridge the gap from modern power conversion to the understanding of systems and network systems with all aspects of power conversion. The methodologies of power-analysis, design of circuits, complex power flow, processing of devices, their modelling and their characterization are introduced along with the demonstration of their relevance to real power-components and -systems. Typical applications include DC-DC conversion for server systems, photovoltaic power conversion, application to microscopic power converters, and high-voltage windcraft systems.

**Inhalte Übung / Content of the exercises**

Written exercises have to be done. For the successful completion of the exercise 50% of the work has to be completed successfully.

**Zu erbringende Prüfungsleistung / Examination result**

schriftliche oder mündliche Abschlussprüfung

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Befragung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

### Drahtlose Sensorsysteme / Wireless Sensor Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5230</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**

With the help of microelectronics many everyday objects have to be connected to realize visions like Pervasive Computing and Ambient Intelligence. Miniaturized, self-powered wireless sensor nodes - also discussed as eGrain or Smart Dust - will make an important contribution to the networking of various objects. Miniaturized sensor nodes for wireless sensor networks represent a design problem, which is characterized by a high degree of functional complexity combined with a significant realization diversity.
In the first part of the lecture behavioral and technological degrees of freedom of a wireless sensor system are presented and discussed intensively. Based on this, special systems such as tire pressure sensors, torque sensors and wireless sensor nodes for a logistics scenario will be discussed in detail.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Modul / Module

### Eingebettete Regelungssysteme Projekt / Embedded Control Project

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5246</th>
<th>Gültig ab: Valid from</th>
<th>01. April 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Modulduauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzungen: Recommended preconditions

- Systemtheorie und Regelungstechnik / Systems and Control
- Systemtheorie und Regelungstechnik II /Systems and Control II
- Modellierung und Systemidentifikation / Modelling and System Identification

### Empfohlenes Fachterm:: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Term week hours</td>
<td>4 Project</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies
### Lernziele / Learning target

Students are able to construct, to model and to simulate a mechatronic system and to design a feedback controller. In particular, they learn how to perform model based controller design and to use a rapid control prototyping approach.

### Inhalte Vorlesung / Content of the lecture

Students develop a mechatronic system of their own choice, i.e. a physical system equipped with sensors, actuators, and microcontrollers, that need feedback control for regular operation. The control is realized via a „Rapid Control Prototyping“ (RCP) system. The physical system will first be modelled, and the controller will be designed, tested, and tuned with help of computer simulations, until a desired specification is met. The control algorithm will then be directly deployed to a special control hardware of the RCP system, without the need of further programming.

### Zu erbringende Prüfungsleistung / Examination result

- written report
- oral presentation at the end of the term

### Benotung / Grading

The module grade is calculated from the result of the written report.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Will be made available to participants at the start of the project.
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells

Modul / Module

Nummer: Number 11LE50MO-5203
Modulverantwortlicher: Responsible person N.N.
Einrichtung: Organisational unit Chair for Process Technology
Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 term
Zugehörige Lehrveranstaltungen: Connected events Lecture
Sprache: Language German

Empfohlenes Fachsemester: Recommended term of study 2 ECTS-Punkte: ECTS-points 3
SWS: Semester week hours 2 Lecture Angebotsfrequenz: Regular cycle Only in the summer term
Arbeitsaufwand: Workload 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

Lernziele / Learning target

The aim of the module is to provide the in-depth theoretical fundamentals and specific skills for the storage and conversion of energy using fuel cells in micro-technical systems.

Inhalte Vorlesung / Content of the lecture

- Physikalisch chemische Grundlagen Brennstoffzellen
- Aufbau und Funktion von Brennstoffzellen
- Vorstellung unterschiedlicher Brennstoffzellentypen
- Physikalisch-chemische Grundlagen der Wasserstoffspeicherung
- Vorstellung von Wasserstoffspeichertypen und -mechanismen
- Diskussion von Vor- und Nachteilen der Wasserstoffspeicher
- Brennstoffzellensysteme im Automobil
- PEM
- DMFC
- Miniaturisierung von Brennstoffzellen
- Mikrobrennstoffzelle
- Chipintegrierte Brennstoffzelle (I²Brenn)
- Brennstoffzellenakkumulator
- Miniaturisierung der Wasserstofferzeugung
- Einsatz von Brennstoffzellensystemen in der MST

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

A handout will be provided.
Modul / Module

Entwurf Analog CMOS Schaltungen / Analog CMOS Circuit Design

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Y. Manoli</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fritz Huettinger Chair of Microelectronics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Zwingende Voraussetzungen: Mandatory preconditions

- System theory (basics)
- Successful participation with a minimum mark of 2.7 in the exam of one of the lectures Microelectronics or Mikroelektronik.

The limited number of seats will be distributed among applying students based on a ranking of the achieved marks.

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td>(56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
Lernziele / Learning target

The module is divided in a lecture and a practical course.

**Lecture**
Illustrated by the examples of simple analog circuits, e.g., amplifiers or reference circuits, this lecture puts its focus on a systematic approach to the analysis of analog circuits. After a successful participation in this course, the student will thus be able to analyze even complex systems.

Another focus is put on two of the most demanding building blocks for mixed-signal circuit design: the analog-to-digital and the digital-to-analog converter. With steadily advancing digitalization, these components have to satisfy the demands for ever increasing bandwidth, resolution and optimum power efficiency. The student will be in the position to choose the right principle for an application based on the different state-of-the-art architectures as well as the major non-idealities which limit their performance.

Finally, sensor readout circuits will be considered as examples of complex electromechanical systems in which the concepts and components considered thus far are put into application. Therewith, the student will be able to break down complex systems to simpler sub-systems and thus reduce the analysis of complex systems to the analysis and interaction of their simpler sub-systems.

**Practical exercise**
Based on the example of a two-stage amplifier with RC compensation, this practical exercise illustrates the typical design flow of an analog integrated circuit. According to the specifications of the amplifier, all transistors will be dimensioned based on hand calculcations at first. Thus, a deeper understanding of this analog circuit will be developed. Next, the circuit will be implemented and simulated on transistor level using the software Cadence Spectre whereby its functionality will be verified. This approach represents an iterative task since the transistor parameters must be varied until all specifications are met. The student will thus learn that hand calculations are an absolute must in order to gain a first insight into the circuit while they also result in a first cut of the circuit for simulations. However, the results of the hand calculations do not present the final cut of the transistor sizes; on the contrary, they may considerably deviate from them.

The last task consists in finalizing the circuit while taking real-life conditions and nonidealities into account, e.g., temperature-, process and parameter variations. The student will thus learn that a successful implementation of an integrated circuit is only possible with a deeper understanding of the circuit’s parameters and their interaction.

At the end of the term, a presentation is to be given which covers the design on transistor level. Therein, the most critical design issues for meeting the specifications are to be explained. Thus, the student will also learn to present his/her results.

---

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illustrated by the examples of simple analog circuits, e.g., amplifiers or reference circuits, this lecture puts its focus on a systematic approach to the analysis of analog circuits. After a successful participation in this course, the student will thus be able to analyze even complex systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
Based on the example of a two-stage amplifier with RC compensation, this practical exercise illustrates the typical design flow of an analog integrated circuit. According to the specifications of the amplifier, all transistors will be dimensioned based on hand calculations at first. Thus, a deeper understanding of this analog circuit will be developed. Next, the circuit will be implemented and simulated on transistor level using the software Cadence Spectre whereby its functionality will be verified. This approach represents an iterative task since the transistor parameters must be varied until all specifications are met. The student will thus learn that hand calculations are an absolute must in order to gain a first insight into the circuit while they also result in a first cut of the circuit for simulations. However, the results of the hand calculations do not present the final cut of the transistor sizes; on the contrary, they may considerably deviate from them.

The last task consists in finalizing the circuit while taking real-life conditions and nonidealities into account, e.g., temperature-, process and parameter variations. The student will thus learn that a successful implementation of an integrated circuit is only possible with a deeper understanding of the circuit's parameters and their interaction. At the end of the term, a presentation is to be given which covers the design on transistor level. Therein, the most critical design issues for meeting the specifications are to be explained. Thus, the student will also learn to present his/her results.

- five graded reports, presentation (at the end of the term)
- The course is successfully passed if the final presentation is passed and an average grade of 70% is achieved in the five written reports.
- Once this prerequisite is fulfilled, the student is allowed to participate in the written exam on the content of both the lecture and the project.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Script
Modul / Module

Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design

Nummer: Number 11LE50MO-5208

Modulverantwortlicher: Responsible person Prof. Dr. Y. Manoli

Einrichtung: Organisational unit Fritz Huettinger Chair of Microelectronics

Modultyp: Module Type Elective Module

Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Laboratory

Sprache: Language English

Empfohlene Voraussetzungen: Recommended prerequisites Successful participation in lecture and practical exercise Analog CMOS Circuit Design (both only offered in summer term, exam to be passed at the end of the summer term).

Empfohlenes Fachsemester: Recommended term of study 3 ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Laboratory Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / Learning target

This practical exercise deals with the layout of the two-stage amplifier with RC compensation which was designed on transistor level in the practical exercise Analog CMOS Circuit Design. It thus represents the second major task in the chain of the design flow of an integrated circuit consisting of “Design on transistor level”, “Layout” and
“Fabrication and Verification”. Students are able to apply basic layout techniques for transistors, resistors, capacitors, and metal layers using industry standard layout und simulation software. They can employ techniques for the reduction of mismatch such as unit elements, multi-finger transistors, interdigitation, common centroid, or guard rings. At the end of the course, the students are able to compare the results of simulations on transistor and layout level so that they can extract the influence of parasitic resistors and capacitors on the overall performance of the amplifier. At the same time, they learn to optimize the layout with respect to these non-idealities.

### Inhalte Vorlesung / Content of the lecture

- Layout of analog CMOS integrated circuits (basics)
- Introduction of the layout tool Cadence VirtuosoXL (industry standard)

### Zu erbringende Prüfungsleistung / Examination result

Graded reports, presentation (at the end of the term)

### Benotung / Grading

The module grade is calculated based on the graded reports and the presentation at the end of the term.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Script
### Flugregelung Laboratory / Flight Control Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5222</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair of Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

The lab course includes topics as part of the HIGHWIND project (Simulation, Optimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

**Empfohlenes Fachsemester: Recommended term of study**

| 2 oder 3 |
| ECTS-Punkte: ECTS-points | 6 |

**SWS: Semester week hours**

| 4 Laboratory |
| Angebotsfrequenz: Regular cycle | Each term |

**Arbeitsaufwand: Workload**

180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
### Personal Profile

- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

### Lernziele / Learning target

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

### Inhalte Praktikum / Content of the laboratory

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles might be remote controlled airplanes with IMUs and GPS or quadrotors, and they might be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

### Zu erbringende Prüfungsleistung / Examination result

**Project work:**
- A working project result
- Project documentation and oral presentation

### Benotung / Grading

The final module grade is determined from an average of the grades of the project documentation and the presentation.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in...
the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Fortgeschrittene Eingebettete Systeme Laboratory / Advanced Embedded Systems Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5223</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Students require basic knowledge of VHDL, good knowledge of C and should be familiar with the basic usage of Linux.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**

The goal is to provide students with the necessary practical background for hardware software codesign.
## Inhalte Praktikum / Content of the laboratory

This course concentrates on hardware-software-co-design, such as combining FPGA-based hardware with high level operating systems running on ARM cores. Students will learn implementing basic hardware structures in VHDL and later proceed to control that hardware directly from high level applications running on the additional ARM core. Students will work either in small groups or on their own.

## Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

## Benotung / Grading

The module grade will be determined from the average of the grades of each report.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Modul / Module

### Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5231</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics, mathematics and micro-optics</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
<th>Angebotsfrequenz: Regular cycle</th>
<th>Only in the summer term</th>
</tr>
</thead>
</table>

| Arbeitsaufwand: Workload | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

### Lernziele / Learning target

In "Advanced topics in micro-optics" we consider aspects of micro-optics in greater depth than is possible in the introductory course Micro-optics, which is a prerequisite. The course
takes an in-depth look at topics ranging from modeling through basic technologies such as multilayers, interferometry and instrumentation, and concludes with advanced concepts such as optofluidics and nanophotonics.

To receive credit for the course, the student will be required to submit a one-page written abstract and then present a 15 minute talk on a topic related to micro-optics.

At the completion of the course, the successful student should possess:
- the ability to understand and analyze multi-lens and thick lens systems;
- an understanding of the basics of numerical modeling as well as characterization techniques for optics;
- the ability to understand the structure and function of some important optical instruments;
- an awareness of the most important devices and effects in MOEMS, nano-optics and tunable optics;
- the ability to understand and apply these concepts in Microsystems applications;
  - the ability to conceive and write a technical abstract as well as give a technical presentation in a conference-like framework.

Inhalte Vorlesung / Content of the lecture

A variety of optical topics with relevance to Microsystems Engineering is considered. Whereas advanced techniques in geometrical optics analysis, optical modeling instruments, and interferometry apply to macro as well as micro-optical systems, the later topics, including optofluidics and nanophotonics, are of prime importance in optical Microsystems and their applications. The course concludes with a look at "The Engineered Eyeball", a design, fabrication and characterization study which utilizes many of the concepts considered in the course.

Table of contents:
1. Optical instrumentation
2. Optics modeling
3. Interferometry
4. Optics characterization
5. Optical multilayers
6. Optofluidics
7. Tunable optics
8. Nanophotonics
  - 9. The engineered eyeball

Zu erbringende Prüfungsleistung / Examination result

oral presentation

Bewertung / Grading

The module grade will be determined from the grade of the presentation.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of
2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- L. Novotny & B. Hecht: Principles of Nano-optics
- W. Smith: Modern Optical Engineering
- S. Gaponenko: Introduction to Nanophotonics
## Modul / Module

### Fortgeschrittenes Praktikum für Mikrocontroller / Advanced Laboratory in Microcontroller

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5233-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Organisational unit:</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration:</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Language:</td>
<td>English</td>
</tr>
<tr>
<td>Voraussetzungen:</td>
<td>Knowledge of the course and laboratory in Micro-controller</td>
</tr>
</tbody>
</table>

**The skills are inspected by an entry test!**

### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>Semester week hours:</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Only in the summer term</td>
<td></td>
</tr>
</tbody>
</table>

### Arbeitsaufwand: Workload

<table>
<thead>
<tr>
<th>Workload:</th>
<th>90 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(56 hours Full-time attendance course of study + 34 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

### Lernziele / Learning target

- Work with microcontroller as a central component
- Tasks targeted in the corresponding areas divide hardware, software and HID with consideration of the issues, ergonomics, noise immunity, reliability, and efficiency of the overall design.
### Inhalte Vorlesung / Content of the lecture

On one µC board several experiments will be executed. The base is a MSP430. Use of existing libraries or creation of your own libraries for existing sensors and interfaces. Other topics are: interrupt security-related hardware, watchdog usage, interfaces, and bus systems.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- MikrocontrollerTechnik Am Beispiel der MSP430-Familie: Matthias Sturm
- Das MSP430 Mikrocontroller Buch: Marian Walter, Stefan Tappertzhofen
- Halbleiter-Schaltungstechnik:Tietze, Schenk; Gamm
<table>
<thead>
<tr>
<th>Modul</th>
<th>Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Magnetische Mikrosysteme / Magnetic Microsystems</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5206</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Wallrabe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Micro-actuators</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

**Lernziele / Learning target**

The purpose of this module is to give an overview of the diverse microsystems having as a chief operating principle the magnetic interactions. Several features specific to magnetic microsystems will be highlighted during the lecture: generation of stable forces without power supply, levitation, remote actuation, electrical generation, high energy density. A special attention will be paid to the building blocks of magnetic microsystems: various technologies to build microcoils, processing of active magnetic materials, and integration of...
Micro-magnets in magnetic microsystems. Several applications will be reviewed, among them: magnetic resonance imaging and spectroscopy at the microscale, motors, generators, electromagnetic microbearings to eliminate friction and wear.

**Inhalte Vorlesung / Content of the lecture**

A brief introduction/reminder of magnetism will be given at the beginning of the lecture covering: magnetic fields and sources of magnetic fields, electromagnetic induction, magnetism and matter.

MEMS processes specific to magnetic microsystems will be reviewed in detail:
- microcoil fabrication techniques for:
  - planar microcoils – spiral and loop coils
  - 3D microcoils – rectangular cross-section, axis parallel to the substrate
  - 3D microcoils – circular cross-section, axis perpendicular to the substrate
  - other techniques
  - processing of thin magnetic layers: deposition, lamination
  - integration of magnetic materials in magnetic microsystems

The third part of the lecture will be dedicated to investigate several magnetic microsystems with specific functionalities. Among them, but not limited to:
- Magnetic resonance. Imaging (MRI) and spectroscopy (NMR)
- Basics
- MRI and NMR at the microscale. The general problem
- Design of MR micro-detectors:
  - Microcoils: planar, 3D
  - Planar microslot waveguide
  - The stripline as an NMR micro-detector
- Electromagnetic levitation. Electromagnetic microbearings
- Device: design and fabrication
- Theory: device characterization
- Electromagnetic energy harvesting
- Eddy current applications
- Proximity sensing and crack detection
- Damping (experiment)
- Scanning mirror using Lorentz force and magnetostatic force

**Zu erbringende Prüfungsleistung / Examination result**

At the beginning of the lecture the students will be presented with a list of topics in connection with the general purpose of the lecture. Each student will have to choose one topic and make a relevant literature review centered on that topic. This literature review will be than presented in an oral presentation followed by a discussion.

**Bewertung / Grading**

The module grade is calculated from the results of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

The lecture slides will be provided as a handout.
Modul / Module

Mikroakustik / Microacoustics

Nummer: Number 11LE50MO-5207

Modulverantwortlicher: Responsible person Prof. Dr. L. Reindl

Einrichtung: Organisational unit Chair Electrical Instrumentation

Modultyp: Module Type Elective Module

Modulbereich: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study 3

ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 lecture + 1 exercises

Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

Students will gain an understanding of the structure, operation and applications of micro acoustic devices. You will learn the basic methods for designing, modeling, for the optimization and for the production of these components. You know the functioning of bulk acoustic wave oscillators, surface acoustic wave components, as well as membrane and Bragg reflector-based thin film components.

You will be able to design and analyze simple "Finite Impulse Response" and "Infinite Impulse Response" filter. Students know the applications of micro acoustic components in
wireless communications and in sensor technology.

**Inhalte Vorlesung / Content of the lecture**

The Micro Acoustics deals with the generation and manipulation of high-frequency (electro-) mechanical waves which enables the realization of high-frequency filters, sensors and actuators. The generation and manipulation is carried out via planar microstructures on piezoelectric materials on which these waves are performed.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modulhandbuch M.Sc. Mikrosystemtechnik – Mikroakustik - Seminar / Microacoustics - Seminar

Modul / Module

Mikroakustik - Seminar / Microacoustics - Seminar

Nummer: Number

11LE50MO-5226

Modulverantwortlicher: Responsible person

Prof. Dr. L. Reindl

Einrichtung: Organisational unit

Chair Electrical Instrumentation

Modultyp: Module Type

Elective Module

Moduldauer Module duration

1 term

Zugehörige Lehrveranstaltungen: Connected events

Seminar

Sprache: Language

German or English

Empfohlenes Fachsemester:: Recommended term of study

3

ECTS-Punkte: ECTS-points

3

SWS: Semester week hours

2 Seminar

Angebotsfrequenz: Regular cycle

Only in the winter term

Arbeitsaufwand: Workload

90 hours

(32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

The seminar micro acoustic offers the opportunity to work independently on a topic of micro acoustic and to present the results in a final presentation.

As part of this work there will be built up based knowledge in specific areas of micro acoustic, and a scientific way of working is trained as well. The independent literature review is an integral part of the seminar paper. There is a personal attention of the seminar participants, which is essentially limited to the clarification of concrete, subject-specific issues. The seminar concludes with an oral exam in the form of the final presentations,
which are followed by a brief discussion.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Modellbildung und Systemidentifikation / Modelling and System Identification

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modellbildung und Systemidentifikation / Modelling and System Identification</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaurer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge of</td>
</tr>
<tr>
<td></td>
<td>- Mathematik I für Ingenieure und Informatiker / Mathematics I für Engineers and Computer Scientists</td>
</tr>
<tr>
<td></td>
<td>- Mathematik II für Ingenieure / Mathematics II für Engineers</td>
</tr>
<tr>
<td></td>
<td>- Differentialgleichungen / Differential Equations</td>
</tr>
<tr>
<td></td>
<td>- Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verwendbarkeit der Veranstaltung / Usability of the module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory Module for students of the study program</td>
</tr>
<tr>
<td>- Master of Science in Embedded Systems Engineering</td>
</tr>
<tr>
<td>Elective Module for students of the study program</td>
</tr>
<tr>
<td>- Master of Science in Informatik</td>
</tr>
<tr>
<td>- Cyber-Physical Systems</td>
</tr>
<tr>
<td>- Kognitive technische Systeme</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik</td>
</tr>
<tr>
<td>- Circuits and Systems</td>
</tr>
<tr>
<td>- Design and Simulation</td>
</tr>
<tr>
<td>- Personal Profile</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering</td>
</tr>
<tr>
<td>- Circuits and Systems</td>
</tr>
<tr>
<td>- Design and Simulation</td>
</tr>
<tr>
<td>- Personal Profile</td>
</tr>
</tbody>
</table>
### Lernziele / Learning target

Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.

### Inhalte Vorlesung / Content of the lecture

Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture manuscript
- Lecture manuscript "System Identification" by J
### Modul / Module

**Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5225</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

#### Empfohlene Voraussetzungen: Recommended preconditions

Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). The course is self contained and can be followed by all students with sufficient background in mathematical systems and control theory. It is recommended not only to master students of engineering, but also to students of computer science, mathematics, and physics. An optimization course (e.g. „Applied Convex and Nonlinear Optimization“ or „Optimal Control and Estimation“) is an advantage, but not necessary.

#### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 lecture + 1 exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
### Learning target

Aim of this module is to give both theoretical background and hands-on practical knowledge in theory and numerics for nonlinear model predictive control (NMPC). In particular, participants shall become able to formulate and to numerically solve NMPC problems with the help of modern computing tools.

### Content of the lecture

The course covers all topics relevant for the theory and numerical solution of nonlinear model predictive control (NMPC) problems. It starts by recalling concepts from systems theory in continuous and discrete time as well as concepts from nonlinear optimization with equalities and inequalities, and the computation of derivatives. The major focus of the course is on the stability theory of NMPC and what impact it can have in control engineering practice. A second focus is on the numerical solution of nonlinear model predictive control and moving horizon estimation problems.

### Content of the exercises

All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python and CasADi (both open-source), and participants are recommended to bring a laptop. At the end of the course, each participant will also start to work on a self-chosen application problem and the results will be presented in a short report and presentation towards at end of the course, after the written exam.

### Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Numerical Optimal Control with Differential Algebraic Equations

### Module Information

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5245</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>Englisch</td>
</tr>
</tbody>
</table>

### Recommended Preconditions

Mathematics such as Calculus, Linear Algebra, basic programming skills, and some familiarity with optimization and control. Previous spring/summer schools on "numerical optimal control" or one or both of the lectures "optimal control and estimation" or "numerical optimization".

### Recommended Term of Study

3 ECTS-Points

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture + 2 Exercises</th>
</tr>
</thead>
</table>

### Workload

90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study)

### Course Usability

Elective Module for students of the study program:
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Fachfremder Wahlbereich Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

Students understand methods for solution of optimal control problems with differential-algebraic equations and can independently apply the acquired knowledge.

### Inhalte Vorlesung / Content of the lecture

The course is divided into two parts:

1. Foundations for Numerical Optimal Control:
   - Python and CasADi, Optimal control with Ordinary Differential Equations, Direct Transcription and Shooting Methods
2. Optimal Control with Differential Algebraic Equations:
   - Formulation, Invariants, Index Reduction, Mechanical and Aerospace Applications

### Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the
module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Numerische Optimierung / Numerical Optimization

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5243</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Semester week hours | 4 lecture + 2 exercises |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 180 hours (96 hours Full-time attendance course of study + 84 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  - Kognitive Technische Systeme
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
Lernziele / Learning target

Students understand important optimization methods used in practice for solution of convex and nonlinear programming problems and can independently apply the aquired knowledge.

Inhalte Vorlesung / Content of the lecture

The course is divided into four major parts:

1. Fundamental Concepts of Optimization: Definitions, Types, Convexity, Duality
2. Unconstrained Optimization and Newton Type Algorithms: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
4. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. Successful participation/solution of at least 50% of the weekly exercise sheets.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004
### Modul / Module

**Numerische Optimierung Projekt / Numerical Optimization Project**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5244</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Numerical Optimization Lecture (participation in the project is only possible for participants of the lecture)</td>
</tr>
</tbody>
</table>

#### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
</table>

#### ECTS-Punkte: ECTS-points

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
</table>

#### SWS: Semester week hours

<table>
<thead>
<tr>
<th>1 project</th>
</tr>
</thead>
</table>

#### Angebotsfrequenz: Regular cycle

<table>
<thead>
<tr>
<th>Only in the winter term</th>
</tr>
</thead>
</table>

#### Arbeitsaufwand: Workload

| 90 hours (16 hours Full-time attendance course of study + 74 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Informatik
  - Kognitive Technische Systeme
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
Lernziele / Learning target

Students can independently program, analyse and apply optimization methods for continuous optimization problems. The project work consists of a computer implementation of one or more self-chosen optimization methods and the application to one or more application problems. The focus could be more on the algorithmic side, e.g. on comparing different algorithm variants, or more on the modelling side, e.g. formulating and solving on interesting optimization problem. The project results are a documented computer code, a project report, and a public presentation.

Zu erbringende Prüfungsleistung / Examination result

Written documentation of the project results
Result of the project and the basis for the project grade is a documented computer code, a report and a brief public presentation in the lecture at the end of the semester.

Zu erbringende Studienleistung / Course Achievement

The students have to participate in the course "Numerische Optimierung / Numerical Optimization - Lecture" in order to be admitted to the final module exam.

Benotung / Grading

The module grade is calculated as 100% of the written report of the project.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

**Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5248</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>

**Zwingende Voraussetzungen: Mandatory preconditions**
- Mathematics such as Calculus, Linear Algebra, basic programming skills, and some familiarity with optimization
- previous spring/summer schools on "numerical optimal control" or one of the lectures "optimal control and estimation" or "numerical optimization"

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 project</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 hours Full-time attendance course of study + 48 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
**Lernziele / Learning target**

Students understand computational methods for solution of optimization problems and can independently apply the acquired knowledge.

**Inhalte Projekt / Content of the project**

The course covers linear, quadratic, conic and nonlinear programming methods and introduces the participants to numerical software packages for each of these problem classes. Also, benchmarking techniques are presented. The course consists of lectures, computer exercises and a project. Theoretical and computer exercises accompany the lecture to deepen the understanding. In the week(s) after the course, participants work on individual projects regarding a software performance comparison, and hand in a written report.

**Zu erbringende Prüfungsleistung / Examination result**

Written report
In the week after the course, students work on individual projects regarding a specific software performance comparison, and hand in a written report which is the basis for the evaluation.

**Benotung / Grading**

The module grade is calculated as 100% of the written report of the project.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

#### Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5249</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). An optimization course (e.g. „Optimal Control and Estimation“) is an advantage, but not necessary.

<table>
<thead>
<tr>
<th>Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study)</td>
</tr>
</tbody>
</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
Lernziele / Learning target

Aim of this intensive course is to give both theoretical background and hands-on practical knowledge in numerical methods to solve optimal control problems for offline and embedded applications such as linear and nonlinear model predictive control. In particular, participants shall become able to formulate and to numerically solve optimal control problems with help of modern computing tools.

Inhalte Vorlesung / Content of the lecture

The course covers all topics relevant for the formulation and practical solution of embedded optimal control problems (OCP). It starts by recalling concepts from numerical simulation of ordinary differential equation models (ODE) and differential algebraic equations (DAE) as well as concepts from convex and nonlinear optimization. The major focus of the course is on direct approaches, in particular on direct collocation, direct single and direct multiple shooting. A second focus is on important application classes such as parameter and state estimation and nonlinear model predictive control (NMPC) and embedded optimization algorithms. The course also treats several implementation details such as the choice of discretization schemes and quadratic programming (QP) solvers. All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python, CVXPY and CasADi (all open-source), and participants are recommended to bring a laptop. In the second week of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards at end of the course, after the written exam.

Inhalte Übung / Content of the exercises

The computer exercises are integral parts of the summer course on numerical optimal control. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the
module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Modulhandbuch M.Sc. Mikrosystemtechnik – Optik-Laboratory
Grundlagen / Basic Optics Laboratory

### Modul / Module

**Optik-Laboratory Grundlagen / Basic Optics Laboratory**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5213</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Gisela and Erwin Sick</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Basic knowledge in physics and mathematics; Knowledge in Micro-optics</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: | Recommended term of study | 2 |
| ECTS-Punkte: | ECTS-points | 3 |
| SWS: | Semester week hours | 2 Laboratory |
| Angebotsfrequenz: | Regular cycle | Only in the summer term |
| Arbeitsaufwand: | Workload | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

### Lernziele / Learning target

The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.

At the completion of the course, the successful student should possess:
• the ability to analyze measurement data and estimate errors;
• the ability to apply error propagation methods;
• the ability to assemble and align optical systems;
• a basic understanding of optical design methods;
• the ability to apply optical measurement techniques;
• the ability to apply analytical and graphical techniques for analyzing optical images.

Inhalte Praktikum / Content of the laboratory

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:
• Statistics and data analysis
• Error propagation
• Focal length of lenses
• Focal length of lens systems
• Construction of a microscope
• Diffraction from gratings
• Newton’s rings
• Fiber optics
• Construction of an interferometer
• Polarization

Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

Bewertung / Grading

The final module grade is determined from an average of the grades of the individual reports.

Gewichtung der Prüfungsleistung / Weight of examination result

• Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literature / Literature

<table>
<thead>
<tr>
<th>Language</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>In English</td>
<td>H. Zappe: Fundamentals of Micro-optics</td>
</tr>
<tr>
<td></td>
<td>E. Hecht: Optics</td>
</tr>
<tr>
<td></td>
<td>B. Saleh &amp; M. Teich: Fundamentals of Photonics</td>
</tr>
<tr>
<td></td>
<td>S. Sinziger &amp; J. Jahns: Microoptics</td>
</tr>
<tr>
<td></td>
<td>W. Smith: Modern Optical Engineering</td>
</tr>
<tr>
<td></td>
<td>P. Hariharan: Basics of interferometry</td>
</tr>
<tr>
<td></td>
<td>R.R. Shannon: The art and science of optical design</td>
</tr>
<tr>
<td></td>
<td>D. Malacara: Optical shop testing</td>
</tr>
<tr>
<td></td>
<td>W.J. Smith: Practical optical system layout</td>
</tr>
<tr>
<td>In German</td>
<td>E. Hecht: Optik</td>
</tr>
<tr>
<td></td>
<td>Walcher: Laboratory der Physik</td>
</tr>
<tr>
<td></td>
<td>Westphal: Physikalisches Laboratory</td>
</tr>
<tr>
<td></td>
<td>Geschke: Physikalisches Laboratory</td>
</tr>
</tbody>
</table>

Modul / Module

Optik-Laboratory Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory

Nummer: Number 11LE50MO-5217

Modulverantwortlicher: Responsible person Prof. Dr. H. Zappe

Einrichtung: Organisational unit Gisela and Erwin Sick Chair of Micro-optics

Modultyp: Module Type Elective Module

Moduldaure: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Laboratory

Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Basic knowledge in physics and mathematics; Knowledge in Micro-optics

Empfohlenes Fachsemester:: Recommended term of study 2 and 3

ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 2 Laboratory + 2 Laboratory

Angebotsfrequenz: Regular cycle Each term

Arbeitsaufwand: Workload 180 hours (60 Hours Full-time attendance course of study + 300 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

Lernziele / Learning target

Basic Optics Laboratory:
The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in
making optical measurements.
At the completion of the course, the successful student should possess:

- the ability to analyze measurement data and estimate errors
- the ability to apply error propagation methods
- the ability to assemble and align optical systems
- a basic understanding of optical design methods
- the ability to apply optical measurement techniques
- the ability to apply analytical and graphical techniques for analyzing optical images

**Advanced Optics Laboratory:**
The Advanced Optics Laboratory Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the curriculum of the 'Optics Lab Course I' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of modern optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:

- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in modern optical setups

**Inhalte Praktikum / Content of the laboratory**

**Basic Optics Laboratory:**
One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:

- Statistics and data analysis
- Error propagation
- Focal length of lenses
- Focal length of lens systems
- Construction of a microscope
- Diffraction from gratings
- Newton's rings
- Fiber optics
- Construction of an interferometer
- Polarization

**Advanced Optics Laboratory:**
This advanced Optics Lab Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the knowledge acquired in the 'Basic Optics Laboratory' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:
- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in optical setups

Table of contents:
- Anamorphic imaging
- Dynamically addressable gratings
- Whispering gallery resonators
- Michelson interferometer and coherence
- Three dimensional light distribution in a 6f system
- Diode pumped solid state laser

### Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required.
The final module grade is determined from an average of the grades of the individual reports of both courses. All experiments must be performed and a lab report written.

### Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports in both courses.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

In English:
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- S. Sinziger & J. Jahns: Microoptics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- D. Malacara: Optical shop testing
<table>
<thead>
<tr>
<th>Basic and Advanced Optics Laboratory</th>
</tr>
</thead>
</table>

- W.J. Smith: Practical optical system layout
- In German:
  - E. Hecht: Optik
  - Walcher: Laboratory der Physik
  - Westphal: Physikalisches Laboratory
  - Geschke: Physikalisches Laboratory
Optimale Steuerung und Estimation / Optimal Control and Estimation

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5241</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

<table>
<thead>
<tr>
<th>Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Lecture 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (84 Hours Full-time attendance course of study + 96 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Cyber,Physical Systems
  - Kognitive Technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
Lernziele / Learning target

Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Riccati Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

Inhalte Vorlesung / Content of the lecture

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearization of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

Inhalte Übung / Content of the exercises

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The
grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Optische Materialien / Optical Materials

- **Nummer:** 11LE50MO-5113-2
- **Modulverantwortlicher:** Prof. Dr. K. Buse
- **Einrichtung:** Chair for Optical Systems
- **Modultyp:** Elective Module
- **Moduldauer:** 1 term
- **Zugehörige Lehrveranstaltungen:** Lecture and exercises
- **Sprache:** English
- **Empfohlene Voraussetzungen:** Knowledge in Micro-optics
- **Empfohlenes Fachsemester:** 3 ECTS
- **ECTS-Punkte:** 5
- **SWS:** 2 lecture + 2 exercises
- **Angebotsfrequenz:** Only in the winter term
- **Arbeitsaufwand:** 150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Circuits and Systems
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - MEMS Processing
    - Photonics
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - MEMS Processing
    - Photonics
    - Personal Profile

Lernziele / Learning target

Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the
fundamentals of light-matter interaction as well as effects that are widely used in many applications. Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.

**Inhalte Vorlesung / Content of the lecture**

1. Classification of optical materials  
2. Fabrication  
3. Interaction of light and matter  
4. Pulse propagation in dispersive materials  
5. Birefringence  
6. Faraday effect  
7. Nonlinear-optical effects  
8. Pockels effect  
9. Kerr effect  
10. Photorefractivity  
11. Frequency conversion  
12. Optical parametric oscillators  
13. Optical whispering galleries

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“</td>
</tr>
<tr>
<td>• A. Yariv, &quot;Photonics: Optical Electronics in Modern Communications&quot;</td>
</tr>
</tbody>
</table>
Module / Module

Optical Properties of Micro and Nano Structures

**Nummer:** 11LE50MO-5211

**Modulverantwortlicher:** PD Dr. A. Gombert

**Einrichtung:** IMTEK

**Modultyp:** Elective Module

**Moduldauer:** 1 term

**Zugehörige Lehrveranstaltungen:**
- Lecture
- Sprache: English

**Empfohlenes Fachsemester:** 3

**ECTS-Punkte:** 3

**SWS:** 2 Lecture

**Angebotsfrequenz:** Only in the winter term

**Arbeitsaufwand:** 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

The objective of this module is learning the fundamentals of technics and physics with respect to the interaction of electro-magnetic waves with predominantly periodically...
structured matter. The students will be enabled to predict the qualitative optical properties of micro and nano structured materials with the taught methods. The superior learning target is to master the fundamental capabilities to design diffractive optical elements and optical elements based on subwavelength structures as well as to know their respective technical applications. The students will obtain the engineering know-how for micro and nano optical elements as used in micro systems technology.

### Inhalte Vorlesung / Content of the lecture

Micro and nano structures have optical properties that differ from macroscopic bodies. The interaction between incident light or more generally incident electromagnetic radiation may lead to a modification of the propagation direction, the polarisation, and the spectral signature of absorption, reflection or transmission. In micro systems or similar technologies these phenomena can be used on purpose or need to be considered when manufacturing micro and nano structures. In this lecture we will work on the theoretical fundamentals as well as on selected applications.

Topics:
- Calculating with complex amplitudes
- Energy transfer at boundaries
- Two beam interference
- Huygens’ principle
- Fresnel’s zone construction
- Introduction into Fourier optics
- Kirchhoff-Fresnel diffraction integral
- Fresnel diffraction
- Fraunhofer diffraction
- Introduction into diffraction gratings
- Spectroscopic gratings
- Theory and applications of subwavelength gratings
- Photonic crystals
- Resonant structures in metals
- Production technologies for micro structures with optical functions

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- E. Hecht: Optics, Addison-Wesley, 1989
## Modul / Module

### Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5219</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair for Bio- and Nanophotonics</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>Recommended term of study</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS:</td>
<td>Semester week hours</td>
<td>3 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(70 Full-time attendance course of study + 110 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

### Lernziele / Learning target

Optical traps and optical micro-manipulation techniques do have the potential to play a key role in future micro- and nanosystems in conjunction with the life sciences. In this lecture the students should learn what is doable with optical forces, where physical limits are and what
is limited by nowadays technology. Besides fascinating fundamental research various applications related to biology or fluctuation based systems are presented. The lecture is manifold and teaches basics in optics, statistical physics and biology/biophysics.

### Inhalte Vorlesung / Content of the lecture

1. Introduction
2. Light - Information carrier and actor
3. About microscopy
4. Light scattering
5. Optical forces
6. Tracking beyond the uncertainty
7. Brownian motion and calibration techniques
8. Photonic force microscopy
9. Applications in cell biophysics
10. Time- multiplexing and holographic optical traps
11. Applications in microsystems technology
12. Applications in nanotechnology

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors.

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its
ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) will be distributed.
### Optische MEMS / Optical MEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Micro-optics</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

- Theoretical understanding of fundamental optical phenomena exploited by the MOEMS technology
- Acquisition of the essential skills necessary for the design, microfabrication, modeling, and characterization of MEMS/MOEMS components
- A comprehensive knowledge of MOEMS based commercial systems and a basic
understanding of the particular applications enabled by MOEMS

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Module 1: MOEMS Fundamentals</strong></td>
</tr>
<tr>
<td>• Optics Review</td>
</tr>
<tr>
<td>• MEMS Manufacturing Techniques</td>
</tr>
<tr>
<td>• Actuators and Position Sensing</td>
</tr>
<tr>
<td>• Design and Modeling</td>
</tr>
<tr>
<td>• Test and Characterization</td>
</tr>
<tr>
<td><strong>Module 2: MOEMS Devices</strong></td>
</tr>
<tr>
<td>• Micromirrors</td>
</tr>
<tr>
<td>• Tunable Gratings</td>
</tr>
<tr>
<td>• Active Microlenses</td>
</tr>
<tr>
<td>• Tunable Optical Resonators</td>
</tr>
<tr>
<td><strong>Module 3: MOEMS Systems</strong></td>
</tr>
<tr>
<td>• Display and Imaging Systems</td>
</tr>
<tr>
<td>• MOEMS in Telecommunication Networks</td>
</tr>
<tr>
<td>• Scientific Instrumentation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMS and MOEMS Related Books</td>
</tr>
<tr>
<td>• An Introduction to Microelectromechanical Systems Engineering by N. Maluf</td>
</tr>
<tr>
<td>• Microsystem Design by Stephen Senturia</td>
</tr>
</tbody>
</table>
- Micromachined Transducers Sourcebook by G. Kovacs
- Fundamentals of Microfabrication by Marc Madou
- Micro Electro Mechanical System Design by J. Allen
- Analysis and Design Principles of MEMS Devices by Minhang Bao
- The MEMS Handbook by Mohamed Gad-el-Hak
- MOEMS: Micro-Opto-Electro-Mechanical Systems by Manouchehr E. Motamedi
- Foundations of MEMS by Chang Liu
- MEMS & Microsystems by Tai-Ran Hsu

Scientific Journals
- Journal of Microelectromechanical Systems / IEEE
- Journal of Micromechanics and Microengineering / IOP
- Journal of Micro/Nanolithography, MEMS, and MOEMS / SPIE
- Microsystem Technologies / SPRINGER
- Sensors and Actuators A-Physical / ELSEVIER
- Applied Optics / OSA
- Optics Letters / OSA
- Optics Express / OSA
- Applied Physics Letters / AIP
- Journal of Biomedical Optics / SPIE
### Modul / Module

**Optoelektronik / Optoelectronics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5229</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Preconditions mandatory</td>
<td>BSc level physics and mathematics; MSc course Micro-optics</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
</table>
**SWS: Semester week hours**

| 2 Lecture | Angebotsfrequenz: Regular cycle | Only in the summer term |

**Arbeitsaufwand: Workload**

| 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

- Optoelectronics is situated at the overlap between optics and electronics and forms the core of the field of photonics. Lasers and LEDs are essential optical semiconductor devices which form the basis for technologies ranging from world-wide high-speed optical data networks to advanced medical instrumentation to high-efficiency indoor lighting.

This course covers the optoelectronics field and introduces the student to the physical principles underlying lasers and quantum light emission; the III-V materials on which almost all optoelectronic components are based; the structure and functionality of laser diodes, LEDs, photodetectors and modulators; and a wide variety of applications for optoelectronic components.
To receive credit for the course, the student will be required to research, write and submit a three-page written paper, using the style of international scientific journals, on a topic related to optoelectronics.

At the completion of the course, the successful student should possess:

- the ability to understand and analyze the essential properties of lasers;
- the ability to understand and analyze the essential properties of photodetectors and modulators;
- an understanding of the basics of III-V materials and their fabrication;
- an awareness of the important physical phenomena on which optoelectronics relies;
- a basic understanding of the physical processes underlying quantum electronics;
- the ability to understand and apply optoelectronic components to microsystems applications;
- the ability to research, plan, and write a technical paper of a standard required for a scientific publication.

### Inhalte Vorlesung / Content of the lecture

- The course considers optoelectronics from the basic photonic and electronic processes, through the materials required, to the individual structures and functionality of the most essential optoelectronic components.

1. Light – wave properties
2. Light – quantum properties
3. Laser resonators
4. Materials and fabrication
5. Macroscopic lasers
6. Light-emitting diodes
7. Semiconductor lasers
8. Laser diode characterization
9. Photodetectors and solar cells
10. Optical modulators
11. Photonic integrated circuits
12. Magneto-, acousto- and non-linear optics
13. Applications in data communications, medicine, lighting and data storage

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course work

The students have to complete assessed course work in order to be admitted to the final module exam. A course work can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework will be communicated at the first class.

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination

### Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- A. Yariv: Optical Electronics
- A. Siegmann: Lasers
- H. Zappe: Laser Diode Microsystems
- M. Fukuda: Optical Semiconductor Devices
- W.T. Silfvast: Laser Fundamenta
## Modul / Module

### Rennautoregelung – Laboratory / Race Car Control Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5224</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzungen: Recommended preconditions

The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
</table>

### SWS: Semester week hours

| 4 Laboratory | Angebotsfrequenz: Regular cycle | Each term |

### Arbeitsaufwand: Workload

| 180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
Personal Profile
- Master of Science in Sustainable Systems Engineering
- Informationstechnik / Information Processing Technology

Learning target
Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

Content of the lecture
Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controlling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer.

The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

Examination result
Project work:
- A working project result
- Project documentation and oral presentation

Grading
The final module grade is determined from an average of the grades of the project work.

Weight of examination result
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RF- und Mikrowellen Design Kurs / RF- and Microwave Design Course</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>11LE50MO-5244</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modulverantwortlicher:</th>
<th>Responsible person</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD Dr. R. Quay</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modultyp:</th>
<th>Module Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Module</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moduldauer</th>
<th>Module duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 term</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen:</th>
<th>Connected events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprache:</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zwingende Voraussetzungen:</th>
<th>Mandatory preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The prior or parallel participation in either module &quot;RF- and microwave devices and circuits&quot; or &quot;RF- and microwave circuits and systems&quot; is required. No prior knowledge of the software is required.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester::</th>
<th>Recommended term of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Punkte:</th>
<th>ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Laboratory</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Angebotsfrequenz:</th>
<th>Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only in the summer term</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand:</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verwendbarkeit der Veranstaltung / Usability of the module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Module for students of the study program</td>
</tr>
<tr>
<td>- Master of Science in Embedded Systems Engineering</td>
</tr>
<tr>
<td>- Circuits and systems</td>
</tr>
<tr>
<td>- Personal Profile</td>
</tr>
<tr>
<td>- Master of Science in Informatik</td>
</tr>
<tr>
<td>- Application area Mikrosystemtechnik</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik</td>
</tr>
<tr>
<td>- Circuits and systems</td>
</tr>
<tr>
<td>- Personal Profile</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering</td>
</tr>
<tr>
<td>- Circuits and systems</td>
</tr>
<tr>
<td>- Personal Profile</td>
</tr>
<tr>
<td>- Master of Science in Sustainable Systems Engineering</td>
</tr>
<tr>
<td>- Energiesysteme / Energy Systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lernziele / Learning target</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students will be enabled to understand, design and layout modern RF- and microwave components and systems by means of the electronic design environment Agilent Advanced</td>
</tr>
</tbody>
</table>
Design System including the two- and three-dimensional electromagnetic simulators Momentum and EMPro 3D. The detailed use of a complex RF-software environment is a dedicated target of this course. This includes the numerical analysis of complex passive and active devices, the design and layout of hybrid and integrated circuits, and their packaging and signal flow. The students will be competent to design and layout passive and active RF-structures including packages and interconnects and circuits of relevance to everyday communication and sensing. The competence includes in-depth understanding and treatment of complex microwave systems and of general system design including the treatment of complex modulated signal flows.

Inhalte Praktikum / Content of the laboratory

The Design Course: RF- and Microwave Systems deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high-level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterisation, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skript: Design Course: RF- and Microwave Systems, R. Quay, 2014 (will be provided at the beginning of the lecture)</td>
</tr>
</tbody>
</table>
### Module

**RF- and Microwave Devices and Circuits**

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5215</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible person:</td>
<td>PD Dr. R. Quay</td>
</tr>
<tr>
<td>Organisational unit:</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Module Type:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration:</td>
<td>1 term</td>
</tr>
<tr>
<td>Lecture:</td>
<td>Connected events</td>
</tr>
<tr>
<td>Language:</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: | 5 |
| ECTS-Punkte: | 3 |
| Semester week hours: | 2 Lecture |
| Angebotsfrequenz: | Only in the winter term |
| Workload: | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

**Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

**Learning target**

The students will be enabled to understand concepts, devices, design, and functioning of modern RF- and microwave transceiver subsystems. This includes the understanding of basic RF-concepts, passive and active devices, circuits, functionalities, their critical figures-of-merit, and the inclusion into modules. The students will be competent to analyse passive and active RF-structures and circuits, which are relevant for any system with an RF-functionality. The competence includes the full understanding of a transmit/receive module.
needed for today’s communication and sensing.

**Inhalte Vorlesung / Content of the lecture**

The lecture RF- and Microwave Devices and Circuits deals with the fundamentals of RF-devices and circuits. It comprises three parts: high-frequency/RF concepts and passive structures, active electronic RF-devices, and RF-circuits and modules. At the interface of modern electronics, dielectric wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern electronics and modern passive RF-technology to the understanding of RF-communication and sensing systems. The methodologies of RF-analysis, design of devices and circuits, and their basic figures-of-merit, their modelling and characterisation are introduced along with the demonstration of their relevance to modern RF- components and microsystems. This also includes a discussion of the underlying technology and many examples supported by RF-design tools from the microwave oven to today’s RF-applications in mobile communication in the iPod.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

RF- and Microwave passives
- Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999
RF-Devices
Modul / Module

**RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5232</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. R. Quay</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

**Lernziele / Learning target**

The students will be enabled to understand concepts, functioning, and design of modern complex RF-and microwave circuits and systems. This includes the understanding of basic RF-concepts, of more complex passive and active circuits, of modern antennas, of combined functionalities, data acquisition, and aspects of systems and communication theory. The students will be competent to analyse passive and active RF-structures and circuits, full RF-functions, analyze complex signal and data flows, and full system concepts.
and data acquisition. System concepts for communication, such as for a full transmit-receive system, for remote sensing including imaging and radar, are presented and several examples discussed in detail.

**Inhalte Vorlesung / Content of the lecture**

The lecture RF- and Microwave Devices and Circuits deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high – level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterization, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering, The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF- and Microwave passives</td>
</tr>
<tr>
<td>Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999</td>
</tr>
<tr>
<td>Further reading material for systems is presented during the lecture.</td>
</tr>
</tbody>
</table>
Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators

**Modul / Module**

**Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators**

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5714</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Design of Microsystems</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:** Recommended term of study
- 2

**ECTS-Punkte:** ECTS-points
- 5

**SWS:** Semester week hours
- 2 lecture + 2 exercises

**Angebotsfrequenz:** Regular cycle
- Only in the summer term

**Arbeitsaufwand:** Workload
- 150 hours (66 hours Full-time attendance course of study + 94 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**
Schaltungskonzepte für ihren Betrieb.

**Inhalte Vorlesung / Content of the lecture**

Die Vorlesung ist in folgende Kapitel gegliedert:
- Einführung in elektronische Bauelemente und Funktionsblöcke (Diode, Bipolartransistor, Stromquellen, Stromspiegel, Bandgap-Referenz, Operationsverstärker)
- Stromliefernde Sensoren (Photodiode, amperometrische Elektrode)
- Spannungslifernde Sensoren (Ionensensitiver Feldeffekttransistor)
- Resistive Sensoren nach dem Wheatstone-Brückenprinzip (Druck, Beschleunigung)
- Kapazitive Sensoren (Druck, Beschleunigung, Feuchte)
- Kapazitive Aktoren (elektrostatisch, piezo)

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Modul / Module

### Systemtheorie und Regelungstechnik II / Systems theory and automatic control II

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5234</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

### Lernziele / Learning target

Students understand important structures used in practice and can independently apply the acquired knowledge. In addition, they master fundamental methods to describe, analyse and control discrete-time systems and multivariable systems. Furthermore, students can design model-based controllers and understand important concepts of nonlinear control.
## Inhalte Vorlesung / Content of the lecture

Based on the Bachelor module "Systemtheorie und Regelungstechnik", advanced methods are discussed to describe, analyze, and control dynamic systems. The course consists of four parts:

The first part focuses on linear single-input single-output (SISO) systems. The methods derived in "systems theory and automatic control I" for continuous-time systems are transferred to discrete-time systems. In particular, the structure of a digital control systems using a analog-to-digital and digital-to-analog converter are discussed. Furthermore, methods to characterize discrete-time systems are introduced such as difference equations, z-transformation, and z-transfer function. The bilinear transformation is introduced in context of controller design.

In the second part, different control structures and design methods for linear SISO systems are discussed which go beyond the standard control loop presented in the course "systems theory and automatic control I". Concepts for feedforward control and disturbance rejection are presented and the basic structure of a cascade controller is discussed. In addition, the internal model controller, the compensation controller and the Smith predictor are treated.

In the third part of the lecture, linear multi-input multi-output (MIMO) systems are treated. The Kalman decomposition is introduced in state space as an important principle to describe the observability and controllability of a MIMO system. Controller design for directly observable systems using pole placement and LQR (Linear Quadratic Regulator) are discussed. Addressing not directly observable systems, the Luenberger observer and the Kalman filter are introduced for state estimation.

The fourth part of the lecture provides an introduction to the control of nonlinear systems. In particular, the concept of Lyapunov stability is treated and used to characterize non-linear systems.

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade
of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Lunze, J.: Regelungstechnik 1 - Systemtheoretische Grundlagen, Analyse und Entwurf einschleifiger Regelungen, Springer
- Unbehauen, H.: Regelungstechnik I - Klassische Verfahren zur Analyse und Synthese linearer kontinuierlicher Regelsysteme, Fuzzy-Regelsysteme, Vieweg + Teubner Verlag
- Unbehauen, H.: Regelungstechnik II - Zustandsregelungen, digitale und nichtlineare Regelsysteme, Vieweg + Teubner Verlag
- Föllinger, O.: Regelungstechnik: Einführung in die Methoden und ihre Anwendung, Hüthig Verlag
VLSI Systementwurf / VLSI System Design

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5216</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Y. Manoli</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fritz-Hüttinger-Chair for Microelectronics</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Successful participation with a minimum mark of 2.7 in the exam of one of the lectures Microelectronics or Mikroelektronik. The limited number of seats will be distributed among applying students based on a ranking of the achieved marks.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile

Lernziele / Learning target

The module is devided in lecture and practical exercise.
Lecture:
The educational objective of the lecture is to convey the methodologies in the design of digital CMOS (complementary metal-oxide semiconductor) integrated circuits. The students
are able to understanding the tool chain and the underlying concepts used in computer aided design (CAD) for microelectronic circuits and use these tools for the design of complex digital circuits. Furthermore the students learn advanced concepts in processor design. The students can use these concepts to implement a complex circuit in FPGA in the accompanying module “VLSI System Design - Laboratory”.

**Practical exercise:**
The educational objective of the practical exercise is that the students get practical hands-on experience with the design of digital circuits using the VHDL hardware description language. They learn all the steps from programming, testing, simulation, communication with external devices, and synthesis to an FPGA. The students learn to work within a group of 4-5 students on a multi-week project, in which they delegate subtasks and establish interface specifications between subgroups. At the end of the course, the students can use VHDL to design a digital circuit and implement this on an FPGA. They understand the basic working principles of microprocessors.

### Inhalte Vorlesung / Content of the lecture

The lecture starts with a general introduction to computer aided design (CAD) for digital CMOS integrated circuits. Based on this background knowledge on the design process of digital systems, the concept of hardware description languages is introduced and VHDL as one of these languages is discussed in detail.

Fundamentals and advanced architectural components of microprocessors form another focus of the lecture. E.g. pipelining and the stack concept are discussed.

Further emphasis is put on the basics, the discussion and comparison of the algorithms (like compiled and event-driven) and scheduling for logic simulation.

The next step towards hardware in the design flow is logic synthesis which is explained from a systematic perspective. The concepts of logic minimization, factorization and technology mapping are covered in this section as well.

Another important aspect for today's VLSI circuits is design for testability. Therefore partitioning and scan-path techniques, external test, test pattern generation (D algorithm and test pattern generation for sequential circuits) and self-test are presented.

Finally - concerning the design flow - the methods of automatic layout and routing are shown in detail. Thereby the layout procedure including design system, layout editor, layout representation, fabrication steps and also layout synthesis are covered. Standard cell layout, global and local routing strategies and also layout compaction are part of this section.

The lecture closes with a discussion of low-power design principles for digital circuits and systems covering the energy-delay-product, the power dissipation of CMOS technology, and alternative related circuit technologies (silicon-on-insulator, pass-gate-logic, reduced-swing-logic, dynamic CMOS, adiabatic logic and charge-recovery-logic). Numerous aspects of power optimization approaches like leakage power reduction methodologies (power gating, multi-Vth-gates, body biasing), leakage and active power reduction by supply voltage reduction (voltage scaling, dynamic voltage scaling, sub-threshold circuits) and active power reduction methodologies (clock gating, asynchronous design) are discussed.

### Inhalte Ubung / Content of the exercises

In the first part, the students familiarize themselves with the VHDL hardware description language. In practical exercises, the students learn the language and the development tools (Xilinx ISE WebPack, ModelSim). Areas covered are VHDL basics, creation of test benches, and simulation.

In the second part, the students implement a small microprocessor in VHDL under
supervision. This serves to further their understanding of VHDL and as the foundation for the final project.

In the third and major part, students are given the task to design and implement an advanced version of the microprocessor, with VGA (Monitor) and PS/2 (Keyboard) interfaces in groups of 4-5 students each. All necessary tools are supplied, such as the complete development environment and FPGA hardware board. The exact design of the processor can be freely determined by the students, as long as it conforms to the provided specification. During the course of the project, special dates are set as milestones to give the students some guidance on their progress. At each of these milestones, students also have to hand in short written reports. The last milestone is the final presentation of the project.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- N. Weste, D. Harris, CMOS VLSI Design: A Circuits and Systems Perspective
- J. L. Hennessy, D. A. Patterson, Computer Architecture. A Quantitative Approach
- P. Ashenden, The Designer's Guide to VHDL
- J. M. Rabaey, Digital Integrated Circuits
- R. L. Geiger, P. E. Allen, N. R. Strader, Very Large Scale Integration Design Techniques for Analogue and Digital Circuits
- W. Wolf, Modern VLSI Design: Systems on Silicon.
## Modul / Module

### Zuverlässigkeitstechnik / Reliability Engineering

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5214</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Assembly and Packaging Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic understanding in mathematics (statistics) as well as materials sciences</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

### SWS: Semester week hours

<table>
<thead>
<tr>
<th>1 Lecture + 1 Übung</th>
</tr>
</thead>
</table>

### Angebotsfrequenz: Regular cycle

Only in the winter term

### Arbeitsaufwand: Workload

90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

### Lernziele / Learning target

It is the aim, that after this module, the student will know:
- The student will have elementary capabilities to solve praxis-relevant.
- He/she will know how experiments can be replaced by simulation and what the
necessary input data are.

- He/she will be able to evaluate Microsystems and more complex electronic and mechatronic systems including software.

- Furthermore it is expected that the student will have improved capabilities in the risk analysis of hazardous applications.

- Also the students be able to report the corresponding results.

### Inhalte Vorlesung / Content of the lecture

1. Definitions
   - 1.1 Quality, dependability, reliability and safety
   - 1.2 Benchmarks for dependability, availability und lifetime
   - 1.3 Statistical description of reliability

2. Dependability of mechanical systems
   - 2.1 Example 1: The ICE-crash at Eschede
   - 2.2 Loads on mechanical components
   - 2.3 Risk factors: notches and cracks
   - 2.4 Fatigue - Woehler's S-N-curve concept
   - 2.5 Computation of operational strength

3. Reliability of electronic hardware
   - 3.1 Automotive electronics: architecture, requirements and quality level
   - 3.2 Reliability of electronic devices, data

4. Reliability data-bases

5. Reliability of systems
   - 5.1 Reliability block-diagram (failure-rate analysis)
   - 5.2 Overview of failure mode analyses
   - 5.3 Fault tree analysis (FTA)
   - 5.4 State-Space: A general method to compute Rs(t) and Fs(t)

6. Reliability of repairable systems
   - 6.1 Definitions
   - 6.2 Repair rate
   - 6.3 Availability
   - 6.4 Markov-Chains and Markov-Processes

7. Software reliability
   - 7.1 Examples of software-induced accidents
   - 7.2 Probability of software faults
   - 7.3 Reliability models for software
   - 7.4 Misjudgements concerning software use

8. Human factors

9. Pre-requisites for development processes

10. Standards and legislation for medical devices

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.
### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Short lecture notes and data files with existing ANSYS macros.
Concentration-Area Microsystems Engineering – Design and simulation
The Concentrations direction "Design and simulation" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

**Modul / Module**

**Computerunterstützte und mechanische Konstruktion / Computer-Aided and mechanic Design**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5502-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Design of Microsystems</td>
</tr>
<tr>
<td>Modulverantwortlich: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

| 3 |

**ECTS-Punkte: ECTS-points**

| 3 |

**SWS: Semester week hours**

| 1 Lecture + 1 Übung |

**Angebotsfrequenz: Regular cycle**

| Only in the winter term |

**Arbeitsaufwand: Workload**

| 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile
Lernziele / Learning target

- Kenntnisse der Vorgehensweise vom Konstruieren am PC
- Praktische Erfahrung mit CAD
- Berechnung und Auslegung einfacher mechanischer Bauelemente
- Verifikation der Auslegung durch mechanische Simulation im CAD System
- CAD Konstruktion eines komplexen Systems

Inhalte Vorlesung / Content of the lecture


Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Dubbel: Taschenbuch für den Maschinenbau, K.-H. Grote, J. Feldhusen. 2011
Kabus: Mechanik und Festigkeitslehre, K. Kabus, 2013
### Modulhandbuch M.Sc. Mikrosystemtechnik – Eingebettete Regelungssysteme Projekt / Embedded Control Project

**Modul / Module**

**Eingebettete Regelungssysteme Projekt / Embedded Control Project**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5246</th>
<th>Gültig ab: Valid from</th>
<th>01. April 2016</th>
</tr>
</thead>
</table>

**Modulverantwortlicher: Responsible person**
Prof. Dr. M. Diehl

**Einrichtung: Organisational unit**
Chair for Systems Control and Optimization

**Modultyp: Module Type**
Elective Module

**Modulduer: Module duration**
1 Term

**Zugehörige Lehrveranstaltungen: Connected events**
Lecture and exercises

**Sprache: Language**
English

**Empfohlene Voraussetzungen: Recommended preconditions**
Vorlesungen / Courses:
- Systemtheorie und Regelungstechnik / Systems and Control
- Systemtheorie und Regelungstechnik II /Systems and Control II
- Modellierung und Systemidentifikation / Modelling and System Identification

**Empfohlenes Fachterm: Recommended term of study**
3

**ECTS-Punkte: ECTS-points**
6

**SWS: Term week hours**
4 Project

**Angebotsfrequenz: Regular cycle**
only in the winter term

**Arbeitsaufwand: Workload**
180 Hours
(64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies
### Lernziele / Learning target

Students are able to construct, to model and to simulate a mechatronic system and to design a feedback controller. In particular, they learn how to perform model based controller design and to use a rapid control prototyping approach.

### Inhalte Vorlesung / Content of the lecture

Students develop a mechatronic system of their own choice, i.e. a physical system equipped with sensors, actuators, and microcontrollers, that need feedback control for regular operation. The control is realized via a „Rapid Control Prototyping“ (RCP) system. The physical system will first be modelled, and the controller will be designed, tested, and tuned with help of computer simulations, until a desired specification is met. The control algorithm will then be directly deployed to a special control hardware of the RCP system, without the need of further programming.

### Zu erbringende Prüfungsleistung / Examination result

- written report
- oral presentation at the end of the term

### Benotung / Grading

The module grade is calculated from the result of the written report.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Will be made available to participants at the start of the project.
# Flugregelung Laboratory / Flight Control Laboratory

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5222</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache:</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>The lab course includes topics as part of the HIGHWIND project (Simulation, Optimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:</td>
<td>2 oder 3</td>
</tr>
<tr>
<td>ECTS-Punkte:</td>
<td>6</td>
</tr>
<tr>
<td>SWS:</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
Personal Profile

- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / Learning目标

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

Inhalte Praktikum / Content of the laboratory

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles might be remote controlled airplanes with IMUs and GPS or quadrotors, and they might be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

Zu erbringende Prüfungsleistung / Examination result

Project work:
- A working project result
- project documentation and oral presentation

Benotung / Grading

The final module grade is determined from an average of the grades of the project documentation and the presentation.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Modul / Module

### Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5503</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Assembly and Packaging Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Assembly and Packaging Technology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile

### Lernziele / Learning target

It is the aim, that after this module, the student will know the fundamental physical problems in electronic hardware based on own numerical investigations. The student will have
elementary capabilities to solve praxis-relevant design problems in assembly and packaging of MEMS using a professional finite-element-system. He/she will know how experiments can be replaced by simulation and what the necessary input data are. He/she will be able to work with the Finite-Element-Code and to modify complex existing models. Furthermore it is expected that the student will have improved capabilities in the analysis of industrial problems and on reporting of the corresponding results.

Zu erbringende Prüfungsleistung / Examination result

Graded protocols and a written or oral exam related to the protocols

Benotung / Grading

The module grade is determined from an average of the grades of the individual reports.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modulhandbuch M.Sc. Mikrosystemtechnik – Kontinuumsmechanik I / Continuum mechanics I

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kontinuumsmechanik I / Continuum mechanics I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4301</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gültig seit: Valid since</td>
<td>01.10.2016</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Department for Sustainable Systems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

### Lernziele / Learning target

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics.

### Inhalte Vorlesung / Content of the lecture

- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic structure of continuum mechanics (kinematics, balance equations, constitutive relations).

The focus lies on the treatment of small deformations and simplified examples with
reference to engineering mechanics.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017</td>
</tr>
<tr>
<td>• M. Itskov, Tensor Algebra and Tensor Analysis for Engineers, Springer, 2013</td>
</tr>
</tbody>
</table>
# Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nummer:</td>
</tr>
<tr>
<td>Gültig seid:</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
</tr>
<tr>
<td>Einrichtung:</td>
</tr>
<tr>
<td>Modultyp:</td>
</tr>
<tr>
<td>Moduldauer</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
</tr>
<tr>
<td>Sprache:</td>
</tr>
<tr>
<td>Nummer:</td>
</tr>
<tr>
<td>Gültig seid:</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
</tr>
<tr>
<td>Einrichtung:</td>
</tr>
<tr>
<td>Modultyp:</td>
</tr>
<tr>
<td>Moduldauer</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
</tr>
<tr>
<td>Sprache:</td>
</tr>
<tr>
<td>Nummer:</td>
</tr>
<tr>
<td>Gültig seid:</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
</tr>
<tr>
<td>Einrichtung:</td>
</tr>
<tr>
<td>Modultyp:</td>
</tr>
<tr>
<td>Moduldauer</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
</tr>
<tr>
<td>Sprache:</td>
</tr>
<tr>
<td>Nummer:</td>
</tr>
<tr>
<td>Gültig seid:</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
</tr>
<tr>
<td>Einrichtung:</td>
</tr>
<tr>
<td>Modultyp:</td>
</tr>
<tr>
<td>Moduldauer</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
</tr>
<tr>
<td>Sprache:</td>
</tr>
</tbody>
</table>

## Empfohlenes Fachsemester:: Recommended term of study

| 3 |

## ECTS-Punkte: ECTS-points

| 6 |

## SWS: Semester week hours

| 2 Lecture + 2 exercises |

## Angebotsfrequenz: Regular cycle

| Only in winter term |

## Arbeitsaufwand: Workload

| 180 hours (64 hours Full-time attendance course of study + 116 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

* Elective Module for students of the study program
  * Master of Science in Mikrosystemtechnik
    * Design and simulation
    * Materials
    * Personal Profile
  * Master of Science in Microsystems Engineering
    * Design and simulation
    * Materials
    * Personal Profile
  * Master of Science in Sustainable Systems Engineering
    * Resilienz / Resilience Engineering

## Lernziele / Learning target

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

## Inhalte Vorlesung / Content of the lecture

* Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
Introduction to the basic structure of continuum mechanics (kinematics, balance equations, constitutive relations).
The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

Inhalte Übung / Content of the exercises

The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
### Kontinuumsmechanik II / Continuum mechanics II

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4303</th>
<th>Gültig seit: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td></td>
<td>Einrichtung: Organisational unit</td>
<td>Department for Sustainable Systems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
<td>Sprache: Language</td>
<td>German or Englisch</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>• Kontinuumsmechanik I / Continuum mechanics I</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

### Lernziele / Learning target

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics.

### Inhalte Vorlesung / Content of the lecture
- Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization
- Balance relations of mechanics and thermomechanics
- Principles of mechanics: principle of D'Alembert, principle of virtual displacements
- Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)
- Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
- P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002
Modul / Module

Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises

| Nummer: Number | 11LE68MO-4304 | Gültig seit: Valid since | 01.10.2016 |
| Modulverantwortlicher: Responsible person |  | Einrichtung: Organisational unit | Department for Sustainable Systems |
| Modultyp: Module Type | Elective module | Moduldauer: Module duration | 1 term |
| Zugehörige Lehrveranstaltungen: Connected events | Lecture | Sprache: Language | German or English |
| Empfohlene Voraussetzungen: Recommended preconditions | • Kontinuumsmechanik I / Continuum mechanics I |  |  |
| | • Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises |  |  |

Empfohlenes Fachsemester: Recommended term of study | 3 | ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture | Angebotsfrequenz: Regular cycle | Only in winter term |
| Arbeitsaufwand: Workload | 90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  o Design and simulation
  o Materials
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Design and simulation
  o Materials
  o Personal Profile
- Master of Science in Sustainable Systems Engineering
  o Resilienz / Resilience Engineering

Lernziele / Learning target

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.
## Inhalte Vorlesung / Content of the lecture

- Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization
- Balance relations of mechanics and thermomechanics
- Principles of mechanics: principle of D'Alembert, principle of virtual displacements
- Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)
- Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

## Inhalte Übung / Content of the exercises

The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

## Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

## Literatur / Literature

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
- P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002
# Lattice Gas Methoden / Lattice Gas Methods

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5504a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair of Simulation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>It is advantageous but not necessary to be familiar with the basic topics of the course “Simulation”.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

## Lernziele / Learning target

Lecture:
The students will learn the basic theoretical descriptions of the Lattice Gas and of the Lattice Boltzmann method and their derivation from kinetic theory. The students will understand the application of these two methods to the computational tasks for the simulation of fluid
Practical exercises:
The students will learn to apply the Lattice Gas method as well as Lattice Boltzmann method to special problems in fluid dynamics. They will be assigned to implement the methods into an algorithm, estimate the computational cost for a given problem, and they will learn to elaborate the result obtained by the simulation and give a detailed interpretation of the fluid flow phenomena under investigation.

Inhalte Vorlesung / Content of the lecture

The lectures will cover the following topics:
- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Formal classical transport theory
- The Boltzmann transport equation (BTE)
- Methods for solving the BTE
- Simple Lattice Gas Method
- Lattice Boltzmann Method

Inhalte Übung / Content of the exercises

This exercise will accompany the topics given in the course on Advanced Topics in Simulation: Lattice Gas Methods. The exercises will focus on problems to be solved with the software tool Mathematica. The students will be assigned with a project to be solved by Mathematica. To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the
module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Sauro Succi: The lattice Boltzmann equation for fluid dynamics and beyond, Oxford University Press, 2001, Fakultätsbibliothek Ang, Wiss, Frei 91: AB/3.0/89</td>
</tr>
<tr>
<td>- Dieter A. Wolf-Gladrow, Lattice gas cellular automata and lattice Boltzmann models, Springer-Verlag, 2000</td>
</tr>
</tbody>
</table>
# Modul / Module

## Modellbildung und Systemidentifikation / Modelling and System Identification

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzungen: Recommended preconditions

- Knowledge of
  - Mathematik I für Ingenieure und Informatiker / Mathematics I für Engineers and Computer Scientists
  - Mathematik II für Ingenieure / Mathematics II für Engineers
  - Differentialgleichungen / Differential Equations
  - Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
</table>

### ECTS-Punkte:ECTS-points

<table>
<thead>
<tr>
<th>6</th>
</tr>
</thead>
</table>

### SWS: Semester week hours

| 2 lecture + 2 exercises |

### Angebotsfrequenz: Regular cycle

| Only in the winter term |

### Arbeitsaufwand: Workload

| 180 hours (64 hours Full-time attendance course of study + 116 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

- Mandatory Module for students of the study program
  - Master of Science in Embedded Systems Engineering

- Elective Module for students of the study program
  - Master of Science in Informatik
    - Cyber-Physical Systems
    - Kognitive technische Systeme
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
### Lernziele / Learning target

Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.

### Inhalte Vorlesung / Content of the lecture

Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture notes
- Lecture notes "System Identification" by J
Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control

Nummer: 11LE50MO-5225

Modulverantwortlicher: Prof. Dr. M. Diehl

Einrichtung: Chair for Systems Control and Optimisation

Modultyp: Elective Module

Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen:
Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). The course is self contained and can be followed by all students with sufficient background in mathematical systems and control theory. It is recommended not only to master students of engineering, but also to students of computer science, mathematics, and physics. An optimization course (e.g. „Applied Convex and Nonlinear Optimization“ or „Optimal Control and Estimation“) is an advantage, but not necessary.

Empfohlenes Fachsemester: 3

ECTS-Punkte: 3

SWS: 2 lecture + 1 exercises

Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
Lernziele / Learning target

Aim of this module is to give both theoretical background and hands-on practical knowledge in theory and numerics for nonlinear model predictive control (NMPC). In particular, participants shall become able to formulate and to numerically solve NMPC problems with the help of modern computing tools.

Inhalte Vorlesung / Content of the lecture

The course covers all topics relevant for the theory and numerical solution of nonlinear model predictive control (NMPC) problems. It starts by recalling concepts from systems theory in continuous and discrete time as well as concepts from nonlinear optimization with equalities and inequalities, and the computation of derivatives. The major focus of the course is on the stability theory of NMPC and what impact it can have in control engineering practice. A second focus is on the numerical solution of nonlinear model predictive control and moving horizon estimation problems.

Inhalte Übung / Content of the exercises

All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python and CasADi (both open-source), and participants are recommended to bring a laptop. At the end of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards the end of the course, after the written exam.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Bewertung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Numerische Optimale Steuerung mit Differentiell-Algebraischen Gleichungen / Numerical Optimal Control with Differential Algebraic Equations**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5245</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Mathematics such as Calculus, Linear Algebra, basic programming skills, and some familiarity with optimization and control. Previous spring/summer schools on &quot;numerical optimal control&quot; or one or both of the lectures &quot;optimal control and estimation&quot; or &quot;numerical optimization&quot;</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Fachfremder Wahlbereich Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

Students understand methods for solution of optimal control problems with differential-algebraic equations and can independently apply the acquired knowledge.

### Inhalte Vorlesung / Content of the lecture

The course is divided into two parts:

1. **Foundations for Numerical Optimal Control:**
   - Python and CasADi, Optimal control with Ordinary Differential Equations, Direct Transcription and Shooting Methods
2. **Optimal Control with Differential Algebraic Equations:**
   - Formulation, Invariants, Index Reduction, Mechanical and Aerospace Applications

### Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Module / Module

### Numerische Optimierung / Numerical Optimization

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5243</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (96 hours Full-time attendance course of study + 84 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  - Kognitive Technische Systeme
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
### Lernziele / Learning target

Students understand important optimization methods used in practice for solution of convex and nonlinear programming problems and can independently apply the acquired knowledge.

### Inhalte Vorlesung / Content of the lecture

The course is divided into four major parts:

- **5. Fundamental Concepts of Optimization:** Definitions, Types, Convexity, Duality
- **6. Unconstrained Optimization and Newton Type Algorithms:** Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
- **7. Equality Constrained Optimization Algorithms:** Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods
- **8. Inequality Constrained Optimization Algorithms:** Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

### Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. Successful participation/solution of at least 50% of the weekly exercise sheets.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004
### Modul ~ Module

#### Numerische Optimierung Projekt / Numerical Optimization Project

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>11LE50MO-5244</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>english</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen:</td>
<td>Numerical Optimization Lecture (participation in the project is only possible for participants of the lecture)</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: | 3 |
| ECTS-Punkte: | 3 |
| SWS: | 1 project |
| Angebotsfrequenz: | Only in the winter term |
| Arbeitsaufwand: | 90 hours |

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  - Kognitive Technische Systeme
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
**Lernziele / Learning target**

Students can independently program, analyse and apply optimization methods for continuous optimization problems. The project work consists of a computer implementation of one or more self-chosen optimization methods and the application to one or more application problems. The focus could be more on the algorithmic side, e.g. on comparing different algorithm variants, or more on the modelling side, e.g. formulating and solving on interesting optimization problem. The project results are a documented computer code, a project report, and a public presentation.

**Zu erbringende Prüfungsleistung / Examination result**

Written documentation of the project results
Result of the project and the basis for the project grade is a documented computer code, a report and a brief public presentation in the lecture at the end of the semester.

**Zu erbringende Studienleistung / Course Achievement**

The students have to participate in the course "Numerische Optimierung / Numerical Optimization - Lecture" in order to be admitted to the final module exam.

**Benotung / Grading**

The module grade is calculated as 100% of the written report of the project.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5248</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Mandatory preconditions:**
- Mathematics such as Calculus, Linear Algebra, basic programming skills, and some familiarity with optimization
- previous spring/summer schools on "numerical optimal control" or one of the lectures "optimal control and estimation" or "numerical optimization"

**Recommended term of study:**
- 3

**ECTS-Punkte: ECTS-points**
- 3

**SWS: Semester week hours**
- 3 project

**Angebotsfrequenz: Regular cycle**
- Only in the winter term

**Workload:**
- 90 hours (42 hours Full-time attendance course of study + 48 Hours Self-study)

**Usability of the module:**
- Elective Module for students of the study program
  - Master of Science in Informatik
    - Fachfremdes Wahlmodul Mikrosystemtechnik
  - Master of Science in Embedded Systems Engineering
    - Circuits and Systems
    - Robotics and Computer Vision
    - Personal Profile
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Sustainable Systems Engineering
    - Informationstechnik / Information Processing Technology
**Lernziele / Learning target**

Students understand computational methods for solution of optimization problems and can independently apply the aquired knowledge.

---

**Inhalte Projekt / Content of the project**

The course covers linear, quadratic, conic and nonlinear programming methods and introduces the participants to numerical software packages for each of these problem classes. Also, benchmarking techniques are presented. The course consists of lectures, computer exercises and a project. Theoretical and computer exercises accompany the lecture to deepen the understanding. In the week(s) after the course, participants work on individual projects regarding a software performance comparison, and hand in a written report.

---

**Zu erbringende Prüfungsleistung / Examination result**

Written report  
In the week after the course, students work on individual projects regarding a specific software performance comparison, and hand in a written report which is the basis for the evaluation.

---

**Benotung / Grading**

The module grade is calculated as 100% of the written report of the project.

---

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Modul / Module

**Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5249</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). An optimization course (e.g. „Optimal Control and Estimation“) is an advantage, but not necessary.

**Empfohlenes Fachsemester:: Recommended term of study**

| 3 |

**ECTS-Punkte: ECTS-points**

| 3 |

**SWS: Semester week hours**

| 2 lecture + 2 exercises |

**Angebotsfrequenz: Regular cycle**

| Only in the winter term |

**Arbeitsaufwand: Workload**

90 hours

(64 hours Full-time attendance course of study + 26 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
Lernziele / Learning target

Aim of this intensive course is to give both theoretical background and hands-on practical knowledge in numerical methods to solve optimal control problems for offline and embedded applications such as linear and nonlinear model predictive control. In particular, participants shall become able to formulate and to numerically solve optimal control problems with help of modern computing tools.

Inhalte Vorlesung / Content of the lecture

The course covers all topics relevant for the formulation and practical solution of embedded optimal control problems (OCP). It starts by recalling concepts from numerical simulation of ordinary differential equation models (ODE) and differential algebraic equations (DAE) as well as concepts from convex and nonlinear optimization. The major focus of the course is on direct approaches, in particular on direct collocation, direct single and direct multiple shooting. A second focus is on important application classes such as parameter and state estimation and nonlinear model predictive control (NMPC) and embedded optimization algorithms. The course also treats several implementation details such as the choice of discretization schemes and quadratic programming (QP) solvers. All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python, CVXPY and CasADi (all open-source), and participants are recommended to bring a laptop. In the second week of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards at end of the course, after the written exam.

Inhalte Übung / Content of the exercises

The computer exercises are integral parts of the summer course on numerical optimal control. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises
The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its
ECTS-points in the calculation of the overall grade.

- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

### Modul / Module

**Optimale Steuerung und Estimation / Optimal Control and Estimation**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5241</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

#### Empfohlene Voraussetzungen: Recommended preconditions

The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

#### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Lecture 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (84 Hours Full-time attendance course of study + 96 Hours Self-study)</td>
</tr>
</tbody>
</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - CyberPhysical Systems
  - Kognitive Technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Riccati Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearization of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

The module grade is calculated from the result of the final examination.
grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

## Modul / Module

### Optimierung / Optimization

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-720</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. F. Kuhn und Prof. Dr. T. Brox</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Algorithms and Complexity / Chair for Image Processing and Computer Graphics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzungen: Recommended preconditions

- Kenntnisse aus den Modulen
  - Einführung in die Programmierung
  - Informatik II – Algorithmen und Datenstrukturen
  - Fortgeschrittene Programmierung
  - Mathematik I für Ingenieure und Informatiker
  - Mathematik II für Informatiker

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

### SWS: Semester week hours

<table>
<thead>
<tr>
<th>1 Lecture + 1 Übung</th>
</tr>
</thead>
</table>

### Angebotsfrequenz: Regular cycle

- only in the summer term

### Arbeitsaufwand: Workload

| 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

- Mandatory Module for students of the study program
  - Bachelor of Science in Informatik

- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - Bachelor of Science in Mikrosystemtechnik
  - Master of Science in Embedded Systems Engineering - Design and simulation - Personal Profile
  - Master of Science in Microsystems Engineering - Design and simulation - Personal Profile
  - Master of Science in Mikrosystemtechnik - Design and simulation - Personal Profile
### Lernziele / Learning target

Die Studierenden lernen, welche Optimierungsprobleme es gibt und wie sie gelöst werden können. Sie sollen die Schwierigkeit von Optimierungsproblemen analysieren und einschätzen lernen und in die Lage versetzt werden, die besprochenen Optimierungsverfahren in Anwendungsfällen einzusetzen.

### Inhalte Vorlesung / Content of the lecture


### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Informatik, Prüfungsordnungsversion 2012: Die Modulnote für das Modul "Graphentheorie und Optimierung" (Teilmodul Optimierung) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Mikrosystemtechnik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Embedded Systems Engineering Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
Modulhandbuch M.Sc. Mikrosystemtechnik – Partikelsimulationsmethoden / Particle Simulation Methods

Modul / Module

Partikelsimulationsmethoden / Particle Simulation Methods

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5505a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair of Simulation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
</tr>
</tbody>
</table>

2 lecture + 2 exercises

Angebotsfrequenz: Regular cycle

Only in the winter term

Arbeitsaufwand: Workload

180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / Learning target

Lecture:
The students will learn about alternative approaches to the simulation of hydrodynamic phenomena relevant for microsystems engineering. They will have a basic understanding of Molecular Dynamics, Dissipative Particle Dynamics and Smoothed Particle Hydrodynamics. They will understand the relation to continuum methods for fluid dynamics. The students will acquire the knowledge on how to apply particle methods to specific problems in microfluidics simulation.
Practical exercises:
The will be able to compile an adequate model for the description of the phenomenon under investigation. They will be able to decide which of the respective particle methods detailed in the lecture to apply for the solution. The students will understand the meaning of particle simulation methods as an experimental tool to investigate materials behaviour through the usage of a particle simulation program and the solution of modeling and simulation assignment.

### Inhalte Vorlesung / Content of the lecture

The lecture will cover the following topics:
- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Molecular Dynamics (MD): Basics
- MD: Numerical Techniques
- Dissipative Particle Dynamics (DPD)
- Smooth Particle Hydrodynamics
- Energy conserving DPD
- Degrees of freedom internal to dissipative particles

### Inhalte Übung / Content of the exercises

These exercises will accompany the topics given in the course on Advanced Topics in Simulation: Particle Methods. The exercises will focus on problems to be solved with the software tool MOLDYN, developed at IMTEK Simulation. Moldyn uses XML input language and provides a wide range of tools for the analysis of results. Direct graphical output can be followed on the computer screen. An interface to Paraview is included to observe different states of the simulation and to produce videos from the results. The students will be assigned with a project to be solved by MOLDYN. To this end a detailed introduction on the usage of MOLDYN will be given.

To pass the exercises, students have to pass minimum 50% of the exercises sheets.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Andrew R. Leach, Molecular modelling: principles and applications, Prentice Hall (2001)
## Rennautoregelung – Laboratory / Race Car Control Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5224</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzung: Recommended preconditions

The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

### Empfohlenes Fachsemester: Recommended term of study

| 3 |

### ECTS-Punkte: ECTS-points

| 6 |

### SWS: Semester week hours

| 4 Laboratory |

### Angebotsfrequenz: Regular cycle

| Each term |

### Arbeitsaufwand: Workload

180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
### Lernziele / Learning target

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

### Inhalte Vorlesung / Content of the lecture

Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controlling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer.

The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

### Zu erbringende Prüfungsleistung / Examination result

Project work:
- A working project result
- Project documentation and oral presentation

### Benotung / Grading

The final module grade is determined from an average of the grades of the project work.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Systemtheorie und Regelungstechnik II / Systems theory and automatic control II

Modul / Module

Number: 11LE50MO-5234

Module Responsible person: Prof. Dr. M. Diehl

Organisational unit: Chair for Systems Control and Optimisation

Module Type: Elective Module

Module duration: 1 term

Connected events: Lecture and exercises

Language: English

Recommended term of study: 3

ECTS-points: 5

Semester week hours: 2 lecture + 1 exercises

Regular cycle: Only in the winter term

Workload: 150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)

Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Learning target

Students understand important structures used in practice and can independently apply the acquired knowledge. In addition, they master fundamental methods to describe, analyse and control discrete-time systems and multivariable systems. Furthermore, students can design...
model-based controllers and understand important concepts of nonlinear control.

**Inhalte Vorlesung / Content of the lecture**

Based on the Bachelor module "Systemtheorie und Regelungstechnik", advanced methods are discussed to describe, analyze, and control dynamic systems. The course consists of four parts:

The first part focuses on linear single-input single-output (SISO) systems. The methods derived in "systems theory and automatic control I" for continuous-time systems are transferred to discrete-time systems. In particular, the structure of a digital control systems using an analog-to-digital and digital-to-analog converter are discussed. Furthermore, methods to characterize discrete-time systems are introduced such as difference equations, $z$-transformation, and $z$-transfer function. The bilinear transformation is introduced in context of controller design.

In the second part, different control structures and design methods for linear SISO systems are discussed which go beyond the standard control loop presented in the course "systems theory and automatic control I". Concepts for feedforward control and disturbance rejection are presented and the basic structure of a cascade controller is discussed. In addition, the internal model controller, the compensation controller and the Smith predictor are treated.

In the third part of the lecture, linear multi-input multi-output (MIMO) systems are treated. The Kalman decomposition is introduced in state space as an important principle to describe the observability and controllability of a MIMO system. Controller design for directly observable systems using pole placement and LQR (Linear Quadratic Regulator) are discussed. Addressing not directly observable systems, the Luenberger observer and the Kalman filter are introduced for state estimation.

The fourth part of the lecture provides an introduction to the control of nonlinear systems. In particular, the concept of Lyapunov stability is treated and used to characterize non-linear systems.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunze, J.: Regelungstechnik 1 - Systemtheoretische Grundlagen, Analyse und Entwurf einschleifiger Regelungen, Springer</td>
<td></td>
</tr>
<tr>
<td>Lunze, J.: Regelungstechnik 2 - Mehrgrößensysteme, Digitale Regelung, Springer</td>
<td></td>
</tr>
<tr>
<td>Unbehauen, H.: Regelungstechnik I - Klassische Verfahren zur Analyse und Synthese linearer kontinuierlicher Regelsysteme, Fuzzy-Regelsysteme, Vieweg + Teubner Verlag</td>
<td></td>
</tr>
<tr>
<td>Unbehauen, H.: Regelungstechnik II - Zustandsregelungen, digitale und nichtlineare Regelsysteme, Vieweg + Teubner Verlag</td>
<td></td>
</tr>
<tr>
<td>Föllinger, O.: Regelungstechnik: Einführung in die Methoden und ihre Anwendung, Hüthig Verlag</td>
<td></td>
</tr>
</tbody>
</table>
VLSI Systementwurf / VLSI System Design

Nummer: 11LE50MO-5216

Modulverantwortlicher: Prof. Dr. Y. Manoli
Einrichtung: Fritz-Hüttinger-Chair for Mikroelektronik

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Zwingende Voraussetzungen:
- Successful participation with a minimum mark of 2.7 in the exam of one of the lectures Microelectronics or Mikroelektronik.
- The limited number of seats will be distributed among applying students based on a ranking of the achieved marks.

Empfohlenes Fachsemester: 2
ECTS-Punkte: 6

SWS: 2 lecture + 2 exercises
Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Circuits and systems
  o Design and simulation
  o Personal Profile
- Master of Science in Mikrosystemtechnik
  o Circuits and systems
  o Design and simulation
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Circuits and systems
  o Design and simulation
  o Personal Profile

Lernziele / Learning target

The module is divided in lecture and practical exercise.
Lecture:
The educational objective of the lecture is to convey the methodologies in the design of digital CMOS (complementary metal-oxide semiconductor) integrated circuits. The students are able to understanding the tool chain and the underlying concepts used in computer
aided design (CAD) for microelectronic circuits and use these tools for the design of complex digital circuits. Furthermore the students learn advanced concepts in processor design. The students can use these concepts to implement a complex circuit in FPGA in the accompanying module “VLSI System Design - Laboratory”.

Practical exercise:
The educational objective of the practical exercise is that the students get practical hands-on experience with the design of digital circuits using the VHDL hardware description language. They learn all the steps from programming, testing, simulation, communication with external devices, and synthesis to an FPGA. The students learn to work within a group of 4-5 students on a multi-week project, in which they delegate subtasks and establish interface specifications between subgroups. At the end of the course, the students can use VHDL to design a digital circuit and implement this on an FPGA. They understand the basic working principles of microprocessors.

Inhalte Vorlesung / Content of the lecture

The lecture starts with a general introduction to computer aided design (CAD) for digital CMOS integrated circuits. Based on this background knowledge on the design process of digital systems, the concept of hardware description languages is introduced and VHDL as one of these languages is discussed in detail. Fundamentals and advanced architectural components of microprocessors form another focus of the lecture. E.g. pipelining and the stack concept are discussed. Further emphasis is put on the basics, the discussion and comparison of the algorithms (like compiled and event-driven) and scheduling for logic simulation. The next step towards hardware in the design flow is logic synthesis which is explained from a systematic perspective. The concepts of logic minimization, factorization and technology mapping are covered in this section as well. Another important aspect for today's VLSI circuits is design for testability. Therefore partitioning and scan-path techniques, external test, test pattern generation (D algorithm and test pattern generation for sequential circuits) and self-test are presented. Finally - concerning the design flow - the methods of automatic layout and routing are shown in detail. Thereby the layout procedure including design system, layout editor, layout representation, fabrication steps and also layout synthesis are covered. Standard cell layout, global and local routing strategies and also layout compaction are part of this section. The lecture closes with a discussion of low-power design principles for digital circuits and systems covering the energy-delay-product, the power dissipation of CMOS technology, and alternative related circuit technologies (silicon-on-insulator, pass-gate-logic, reduced-swing-logic, dynamic CMOS, adiabatic logic and charge-recovery-logic). Numerous aspects of power optimization approaches like leakage power reduction methodologies (power gating, multi-Vth-gates, body biasing), leakage and active power reduction by supply voltage reduction (voltage scaling, dynamic voltage scaling, sub-threshold circuits) and active power reduction methodologies (clock gating, asynchronous design) are discussed.

Inhalte Übung / Content of the exercises

In the first part, the students familiarize themselves with the VHDL hardware description language. In practical exercises, the students learn the language and the development tools (Xilinx ISE WebPack, ModelSim). Areas covered are VHDL basics, creation of test benches, and simulation. In the second part, the students implement a small microprocessor in VHDL under supervision. This serves to further their understanding of VHDL and as the foundation for
In the third and major part, students are given the task to design and implement an advanced version of the microprocessor, with VGA (Monitor) and PS/2 (Keyboard) interfaces in groups of 4-5 students each. All necessary tools are supplied, such as the complete development environment and FPGA hardware board. The exact design of the processor can be freely determined by the students, as long as it conforms to the provided specification. During the course of the project, special dates are set as milestones to give the students some guidance on their progress. At each of these milestones, students also have to hand in short written reports. The last milestone is the final presentation of the project.

### Zu erbringende Prüfungsleistung / Examination result
- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading
The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature
- N. Weste, D. Harris, CMOS VLSI Design: A Circuits and Systems Perspective
- J. L. Hennessy, D. A. Patterson, Computer Architecture. A Quantitative Approach
- P. Ashenden, The Designer's Guide to VHDL
- J. M. Rabaey, Digital Integrated Circuits
- R. L. Geiger, P. E. Allen, N. R. Strader, Very Large Scale Integration Design Techniques for Analogue and Digital Circuits
- W. Wolf, Modern VLSI Design: Systems on Silicon.
Concentration-Area Microsystems Engineering –

Life sciences: Biomedical engineering

The Concentration direction "Life sciences: Biomedical engineering" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

### Modul / Module

<table>
<thead>
<tr>
<th>Oberflächenanalyse / Surface Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nummer:</strong> Number</td>
</tr>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
</tr>
<tr>
<td><strong>Empfohlenes Fachsemester:</strong> Recommended term of study</td>
</tr>
<tr>
<td><strong>ECTS-Punkte:</strong> ECTS-points</td>
</tr>
<tr>
<td><strong>SWS:</strong> Semester week hours</td>
</tr>
<tr>
<td><strong>Angebotsfrequenz:</strong> Regular cycle</td>
</tr>
<tr>
<td><strong>Arbeitsaufwand:</strong> Workload</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target
The performance of microsystems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in microsystems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of microsystems engineering.

Inhalte Vorlesung / Content of the lecture

The techniques presented are grouped into three general topics which are imaging of surfaces (electron microscopy, scanning probe techniques), chemical analysis (XPS, SIMS, FTIR) of the composition of surfaces and methods for the determination of thicknesses (Ellipsometry, XRR, Surface Plasmon Spectroscopy) of layers. General topics from the surface sciences such as adhesion, wetting, and adsorption processes are also presented together with the techniques.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Various materials are available on the website.
# Modulhandbuch M.Sc. Mikrosystemtechnik – Ausgewählte Problemstellung in Biosignalverarbeitung / Selected Problems in Biosignal Processing

<table>
<thead>
<tr>
<th>Modul / Module</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ausgewählte Problemstellung in Biosignalverarbeitung / Selected Problems in Biosignal Processing</td>
<td></td>
</tr>
</tbody>
</table>

## Nummer: Number
11LE50MO-5303

### Modulverantwortlicher: Responsible person
Prof. Dr. U. Hofmann

### Einrichtung: Organisational unit
Faculty of Medicine

### Modultyp: Module Type
Elective Module

### Modul dauer: Module duration
1 term

### Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

### Sprache: Language
English

### Empfohlene Voraussetzungen: Recommended requirements
Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one „programming“ language like Python (preferably), Matlab (or Octave) or even IDL (not supported).

### Empfohlenes Fachsemester: Recommended term of study
2

### ECTS-Punkte: ECTS-points
3

### SWS: Semester week hours
2 Lecture + 1 Übung

### Angebotsfrequenz: Regular cycle
Only in the winter term

### Arbeitsaufwand: Workload
90 hours
(42 Hours Full-time attendance course of study + 48 Hours Self-study)

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

## Lernziele / Learning target

Participants will learn to interpret and analyze biological signals of high bandwidth. They will
- gain a deep knowledge of feature extraction methods,
- utilize selected classification methods and
• decision making methods.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
### Bioaktive Polymeroberflächen / Bioactive Polymer Surfaces

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5321</th>
<th>Gültig seid: Valid since</th>
<th>02.09.2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Rühe</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended requirements</td>
<td>- General knowledge of organic chemistry - General knowledge of macromolecular chemistry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

The aim of this module is to enable you to
- understand the basic physical properties of polymer surfaces
- get to know fabrication processes of polymer surfaces
- understand different kinds of bioactivity, their mechanisms, and their applications
- understand the interaction of polymer surfaces with organisms
### Inhalte Vorlesung / Content of the lecture

- Surface properties
- Synthesis of functional polymer surfaces: non-covalent and covalent attachment, coating of surfaces with polymers, microstructuring of polymer surfaces
- Interaction of polymer surfaces with biomolecules and cells
- Antimicrobial, protein-resistant and antifouling polymer surfaces, DNA immobilization on surfaces, DNA origami, immunoactive polymer surfaces, etc.
- Special applications

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Literature recommendations will be provided with the lecture material.
**Bioaktive Polymeroberflächen mit Seminar / Bioactive Polymer Surfaces with seminar**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5322</th>
<th>Gültig seit: Valid since</th>
<th>02.09.2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Rühe</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended requirements</td>
<td>- General knowledge of organic chemistry - General knowledge of macromolecular chemistry</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 1 exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

The aim of this module is to enable you to
- understand the basic physical properties of polymer surfaces
- get to know fabrication processes of polymer surfaces
- understand different kinds of bioactivity, their mechanisms, and their applications
- understand the interaction of polymer surfaces with organisms
- learn to work with original research papers

**Inhalte Vorlesung / Content of the lecture**

- Surface properties
- Synthesis of functional polymer surfaces: non-covalent and covalent attachment, coating of surfaces with polymers, microstructuring of polymer surfaces
- Interaction of polymer surfaces with biomolecules and cells
- antimicrobial, protein-resistant and antifouling polymer surfaces, DNA immobilization on surfaces, DNA origami, immunoactive polymer surfaces, etc.
- special applications

**Inhalte Übung / Content of the exercises**

In this exercise class, you will work with original research papers and write a short review of selected topics.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course achievement**

The tutorials help the students to get a more in depth and thorough understanding of the topic. Students will work with original research papers and have to write a short review of a selected topic which will be evaluated.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature recommendations will be provided with the lecture material.</td>
</tr>
</tbody>
</table>
**Module / Module**

**Biomedizinische Messtechnik I / Biomedical Instrumentation I**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5301</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

**Lernziele / Learning target**

The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to record electrical signals out of the human body and to understand and the technical and medical background of the most important (electrical) diagnosis methods.

The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical instrumentation with respect to bioelectrical signals. The students will be enabled to design and develop fundamental amplifier circuits and learn about the physiological effects of electrical hazards and will be able to apply basic mechanisms and measures to provide electrical safety. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering.
### Inhalte Vorlesung / Content of the lecture

The course introduces different aspects of the recording of bioelectrical signals starting with the nerve and including amplifier design. It presents the most important medical diagnosis methods in the field of bioelectrical signals. In detail, the following topics will be covered:

- Origin of bioelectrical signals
- Electrochemistry of electrodes
- Acute and chronic applications of electrodes
- Recording and amplification of bioelectrical signals
- Interference and artefacts
- Bioelectrical signals of peripheral nerves and the muscle
- Electrical signals of the heart (ECG)
- Cardiac pacemakers and implantable defibrillators
- Technical safety of medical devices

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination systems.

### Inhalte Übung / Content of the exercises

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual copies of the slides will be delivered accompanying to the lectures. Literature:</td>
</tr>
<tr>
<td><strong>English</strong></td>
</tr>
<tr>
<td><strong>German</strong></td>
</tr>
<tr>
<td>• Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005</td>
</tr>
</tbody>
</table>
## Biomedizinische Messtechnik II / Biomedical Instrumentation II

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomedizinische Messtechnik II / Biomedical Instrumentation II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>11LE50MO-5302</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nummer:</td>
<td>Number</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Elective Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moduleverantwortlicher:</th>
<th>Prof. Dr. T. Stieglitz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Einrichtung:</th>
<th>Chair for Biomedical Microtechnology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisational unit:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module duration</th>
<th>1 term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moduldauer:</td>
<td>Module duration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen:</th>
<th>Lecture and exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected events:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprache:</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended term of study</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Punkte:</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-points</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS:</th>
<th>2 lecture + 1 exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester week hours</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angebotsfrequenz:</th>
<th>Only in the winter term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular cycle</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand:</th>
<th>90 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td></td>
</tr>
</tbody>
</table>

| (48 Hours Full-time attendance course of study + 42 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

### Lernziele / Learning target

The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to acquire non-electrical measurement categories out of the human body and to impart knowledge about the technical and medical background of the most important imaging methods in medicine. The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical terms with respect to cardiovascular diagnosis and imaging techniques. The students will get an overview of the application areas of the different methods and the technical background of the underlying measurement principles and measurement systems. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering.
Inhalte Vorlesung / Content of the lecture

The course introduces methods to acquire non electrical cardiovascular parameters as well as the most important medical imaging techniques.

- Measurement of cardiovascular parameters: blood pressure, physiology, pressure, measurement according to Riva Rocci & oscillometric
- Measurement of cardiovascular parameters: blood flow, electromagnetic measurement principle
- Measurement of cardiovascular parameters: blood flow, ultrasound measurement principle
- Imaging techniques: x-ray
- Imaging techniques: systems theory of imaging systems, digital signal processing
- Imaging techniques: computer tomography
- Biological effect of ionizing radiation / dosimetry
- Imaging techniques in nuclear medicinal diagnosis
- Imaging techniques: ultrasound
- Imaging techniques: thermography and impedance tomography
- Imaging techniques: electrical sources, optical tomography, endoscopy
- Imaging techniques: MR tomography
- Imaging techniques: molecular imaging

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Inhalte Übung / Content of the exercises

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual copies of the slides will be delivered accompanying to the lectures. Literature:</td>
</tr>
</tbody>
</table>

**English**

**German**
- Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005
Biomedizinische Messtechnik - Laboratory / Biomedical Instrumentation - Laboratory

**Nummer: Number** 11LE50MO-5304

**Modulverantwortlicher: Responsible person** Prof. Dr. T. Stieglitz

**Einrichtung: Organisational unit** Chair for Biomedical Microtechnology

**Modultyp: Module Type** Elective Module

**Moduldauer Module duration** 1 term

**Zugehörende Lehrveranstaltungen: Connected events** Laboratory

**Sprache: Language** English

**Zwingende Voraussetzungen: Mandatory preconditions**
The successful participation in the modules "Biomedizinische Messtechnik I / Biomedical Instrumentation I" is a prerequisite for admission to this module.

**Empfohlene Voraussetzungen: Recommended preconditions** Basic knowledge in mathematics and natural sciences

**Empfohlenes Fachsemester:. Recommended term of study** 3

**ECTS-Punkte: ECTS-points** 3

**SWS: Semester week hours** 4 Laboratory

**Angebotsfrequenz: Regular cycle** Only in the winter term

**Arbeitsaufwand: Workload** 90 hours
(64 hours Full-time attendance course of study + 26 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

**Lernziele / Learning target**

Learning targets and scientific objectives are the acquisition of scientific knowledge and practical skills to independently record bioelectrical signals and apply and transfer this theoretical knowledge of signal acquisition and noise and artefact suppression into practical
applications. This module teaches the students the recording of bioelectrical signals from the human body, the handling of surface electrodes, the development of simple electronic circuits and the fundamentals of digital signal processing of bioelectrical signals with the help of Software packages to develop automatic signal acquisition routines.

**Inhalte Praktikum / Content of the laboratory**

Within this laboratory, practical exercises will be performed in small groups with a maximum of three participants. In the first part of the course program, diagnostic measures like blood pressure, signals from the heart (electrocardiogram) and muscle (electromyogram), and the determination of the motor nerve conduction velocity will be learned. Characteristic parameters will be extracted from the signals as basis for diagnosis in medicine.

The students design and develop independently an electronic amplifier circuit to record muscle signals as well as a graphical user interface to display these signals and control a technical artefacts (e.g. a cursor on the screen or a small robotic hand) with these muscle signals. The performance of this simple man-machine-interface will be eventually evaluated under real-life conditions.

**Zu erbringende Prüfungsleistung / Examination result**

Several written tests as well as evaluation of a written documentation concerning the development of „Men-Computer-Interface“.

For the practical exercises, attendance is mandatory. It is possible to ask for auxiliary dates and to have access to the chair’s labs outside the exercise sessions.

**Benotung / Grading**

The final module grade is determined from an average of the grades of the individual reports and tests.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

**BioMST 1 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 1 – Biotechnological Tasks for Microsystems Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5315</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

#### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
</table>

#### ECTS-Punkte: ECTS-points

| 6 |

#### SWS: Semester week hours

| 2 lecture + 2 exercises |

#### Angebotsfrequenz: Regular cycle

| Each term |

#### Arbeitsaufwand: Workload

| 180 hours (56 oder 64 hours Full-time attendance course of study + 116 oder 124 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target

Die Studierenden gewinnen grundlegende Kenntnisse über das Spektrum der Biotechnologie und in den Teilbereichen der Mikro- und Molekularbiologie. Anhand ausgewählter Beispiele aus verschiedenen Bereichen der Biotechnologie gewinnen Sie ein Verständnis dafür wie durch den Einsatz der Mikrosystemtechnik mikro- und molekularbiologische Probleme vorteilhaft gelöst werden können. Ferner erhalten die

Laboratory „BioMST 1: Grundtechniken der Molekularbiologie:

Inhalte Vorlesung / Content of the lecture

Anhand ausgewählter Beispiele wird gezeigt, wie durch den Einsatz der Mikrosystemtechnik biotechnologische Probleme vorteilhaft gelöst werden können. Dabei wird Bezug genommen auf aktuelle Entwicklungen gemaner und internationaler Forschungseinrichtungen sowie der Industrie. Ferner werden Strategien zur Identifizierung neuer Anwendungen der Mikrosystemtechnik im Bereich Biotechnologie aufgezeigt. Die Themen der LVA sind:

- Spektrum der Biotechnologie
- BioMST Roadmap
- Molekulare Biotechnologie
- Wissenschaftliche Grundlagen
- Instrumentierung & Automatisierung
- Mikrobiologische Methoden
- Molekularbiologische Methoden
- Funktionsanalytik
- Gastvortrag aus der Industrie

Inhalte Praktikum / Content of the laboratory

Das Laboratory ist als 4 tägiger Block ausgelegt. 4 Wochen vor dem Laboratory bekommt jeder Teilnehmer/in ein Thema zugeordnet, über das er/sie ein 15 minütiges Referat am ersten Tag hält ums so zum einen zu zeigen, dass auch ein biochemischer Stoff aufgearbeitet werden kann und um zugleich den anderen Kursteilnehmern/innen den Stoff aus eigener Sicht nahe zu bringen. Zu den einzelnen Versuchen sind Protokolle zu schreiben.

Vor Beginn der Versuche wird eine Sicherheitsbelehrung durchgeführt um überhaupt im Biolabor arbeiten zu dürfen. Folgende Experimente werden durchgeführt:

- Zellkulturtechniken werden erlernt, um einerseits steril arbeiten zu können und andererseits etwas Erfahrung im Umgang und der Aufzucht von Bakterien und Zellen zu erhalten. Um zu wissen wie viele Zellen vorhanden sind, werden verschiedene Zellzählungsmethoden angewendet.

Eine weitere Standardtechnik ist der Immunoassay. Hierbei wird ein Protein, welches sich aus einem entsprechenden Gen ableitet, quantitativ nachgewiesen. Es wird sowohl die klassische Methode in der Mikrotiterplatte als auch in einem zentrifugalen System durchgeführt. Hierbei soll insbesondere in der Handhabung und im Nachweis der Unterschied zwischen DNA und Protein erlernt werden.

Als letzte Technik wird die Elektrophorese durchgeführt. Sie dient sowohl zum Nachweis von DNA als auch Proteinen. Hierbei soll der Umgang mit Gelen und wie man die erhaltenen Daten ausliest erlernt werden.

Fragen, Anregungen und Änderungswünsche sind jederzeit willkommen, da wir versuchen das Laboratorium so zu gestalten, dass innerhalb kurzer Zeit ein maximales Verständnis für diese recht komplexen Techniken der Biologen erreicht werden kann. Die Praktikumsnote setzt sich zusammen aus einem Kurzreferat zu einem Experimentalthema des Praktikums sowie der Erstellung eines Praktikumsberichtes.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Begleitend zur Lecture wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
### Modul / Module

**BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 2 – Biotechnological Tasks for Microsystems Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5317</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target


**Inhalte Vorlesung / Content of the lecture**

Anhand ausgewählter Beispiele wird gezeigt, wie durch den Einsatz der Mikrosystemtechnik biotechnologische Probleme vorteilhaft gelöst werden können. Dabei wird Bezug genommen auf aktuelle Entwicklungen germaner und internationaler Forschungseinrichtungen sowie der Industrie. Ferner werden Strategien zur Identifizierung neuer Anwendungen der Mikrosystemtechnik im Bereich Biotechnologie aufgezeigt. Die Themen der LVA sind:

- Bioverfahrenstechnik
- Bereiche und Aufgaben
- Bioverfahrensentwicklung
- UP-Stream Prozesse & Stoffumwandlung
- Down-Stream Prozesse Diagnostik
- Diagnostik
- Mikroorganismen in Lebensmitteln
- Bakterien & Viren als Krankheitserreger
- Klassisch Mikrobiologische Diagnostik
- Immun- und Nukleinsäurebasierte Diagnostik von Erregern
- Automatisierung, Miniaturisierung und Integration
- Systementwicklung, Validierung und QM

**Zu erbringende Prüfungsleistung / Examination result**

- written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begleitend zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.</td>
</tr>
</tbody>
</table>
### Modul / Module

**Biophysik der Zelle / Biophysics of the cell**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5305</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Bio- and Nanophotonics</td>
</tr>
<tr>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

**SWS: Semester week hours**

<table>
<thead>
<tr>
<th>3 Lecture + 2 Übung</th>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only in the winter term</td>
<td></td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

| 180 hours (80 Hours Full-time attendance course of study + 100 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

This module gives a survey through modern cell biophysics, addresses state of the art scientific questions and presents modern investigation methods. This comprises classical but also novel physical methods and theories, which pushed the field of biophysics together with newest measurement technology. The applied physical methods do not only inspire biology and medicine, but also the physics of complex systems, which achieves an unequaled level of self-organisation and complexity inside living cells. This lecture is
Modulhandbuch M.Sc. Mikrosystemtechnik – Biophysik der Zelle / Biophysics of the cell

designed for physicists and engineers and provides a colorful mixture of physics, biology, chemistry, mathematics, and engineering that is illustrated with numerous pictures and animations.

**Inhalte Vorlesung / Content of the lecture**

- Structure of the cell or the recipe for cell-biophysical science
- Diffusion and Fluctuation
- Sensing and Acting measurement principles
- Biological relevant forces
- Biophysics of proteins
- Polymerphysics
- Visco-elasticity and micro rheology
- Dynamics of the cytoskeleton
- Molecular motors
- Membranephysics

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

**Inhalte Übung / Content of the exercises**

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors.

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the
module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Joe Howard: Mechanics of Motor Proteins and the Cytoskeleton.

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
DNA Analytik / DNA Analysis

The key principles of DNA analysis are taught using standard and high tech applications to demonstrate the underlying mechanisms of DNA analysis. Starting with the biochemical role of the DNA the principles of enzymatic modification and physical detection of nucleic acids are covered. PCR is used as a demo application to introduce the key features of DNA analysis. From there on the areas of sequencing and DNA microarrays are covered as well as the use of databases to gain information about DNA sequences and how to design DNA primers and probes. The technical equipment to perform PCR, gel electrophoresis, microarray production and readout is also addressed. The lecture should give the student the theoretical background to understand, plan and perform DNA analysis research.
## Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Structure and function of DNA
- Enzymes that process DNA
- DNA amplification (PCR)
- DNA detection (gel electrophoresis, ...)
- Application in forensic sciences
- DNA microarray overview

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the results of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

## Literatur / Literature

Various materials are available on the website [http://www.cpi.uni-freiburg.de/](http://www.cpi.uni-freiburg.de/)
Modul / Module

**Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Egert</td>
</tr>
<tr>
<td>Organisational unit</td>
<td>Chair for Biomicrotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen / Interest in interdisciplinary processing of up-to-date problems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td>(28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

**Lernziele / Learning target**

den empirischen und interagierenden Zugängen der Neurowissenschaften in einen konstruktiven und kontroversen Dialog gebracht werden.

**Inhalte Seminar / Content of the seminar**

Interdisziplinäres Seminar zu ethischen und philosophischen Aspekten der Neurotechnologie.

Folgende Themenbereiche werden jeweils unter ethischen, neurowissenschaftlichen bzw. ingenieurwissenschaftlichen Gesichtspunkten bearbeitet:

1. Ethik der Neurowissenschaften als aktuelles Gebiet der Philosophie
2. Identität, Person und Persönlichkeit als Grundbegriffe der Ethik der Neurowissenschaften
3. Spezifische philosophische und ethische Aspekte folgender Anwendungsfelder:
   - Invasive und nicht-invasive Gehirn-Maschine-Schnittstellen
   - Neuroimaging- Emotionale Integration neuronaler Prothesen
   - Tiefe Hirnstimulation
   - Optogenetische Interaktion
   - Neuro-Enhancement
   - Zukunftstechnologien und deren Einsatz

**Zu erbringende Prüfungsleistung / Examination result**

mündliche Abschlussprüfung / Oral examination

**Bewertung / Grading**

Die Modulnote errechnet sich zu 100% aus der mündlichen Abschlussprüfung. The module grade is calculated 100% from the results of the final oral examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**


**Literatur / Literature**

- Lecture notes
**Modul / Module**

**Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5407</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

Biochip technologies play a key role in the miniaturization and parallelization of bioanalytical techniques. They combine microbiological methods with microsystems engineering. The students will understand the requirements for the integration of modern bioanalytical methods in miniaturized devices. Special emphasis will be given to bioanalytical surfaces and surface architectures and the students will learn how to apply such concepts to chip-based bioanalytical assays.
<table>
<thead>
<tr>
<th><strong>Inhalte Vorlesung / Content of the lecture</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Interaction of surfaces with biological environments</td>
</tr>
<tr>
<td>• Design criteria for bioanalytical surfaces and interfaces</td>
</tr>
<tr>
<td>• Procedures and techniques for biochip fabrication</td>
</tr>
<tr>
<td>• Nucleic acid based biochips</td>
</tr>
<tr>
<td>• Protein biochip technologies</td>
</tr>
<tr>
<td>• Complex biochip applications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Zu erbringende Prüfungsleistung / Examination result</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Benotung / Grading</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Gewichtung der Prüfungsleistung / Weight of examination result</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials will be provided through the ILIAS system. An ILIAS page will be generated prior to the start of the course and communicated to the students.</td>
</tr>
</tbody>
</table>
Modul / Module

Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation

Nummer: Number 11LE50MO-5306

Modulverantwortlicher: Responsible person Prof. Dr. T. Stieglitz

Einrichtung: Organisational unit Chair for Biomedical Microtechnology

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture

Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study 3

ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Lecture

Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Objective of the module is to impart knowledge of the medical and biological as well as the physicochemical and technical fundamentals during electrical stimulation of nerve and muscle that are mandatory for any engineer to understand the biological processes and to design and develop technical aids and processes in the field of neural prostheses and neuromodulation.

The module teaches the students the theoretical background with respect to effects, hazards and damaging mechanisms of electrical stimulation in the peripheral and central nervous system as well as the electrochemical processes that have to be taken into account in neuro-technical interfaces.
# Inhalte Vorlesung / Content of the lecture

The lecture introduces biological-medical as well as physico-technical aspects during electrical stimulation of nerves and muscles. The following topics will be covered:

- Overview of the history of electrical stimulation
- Anatomy and physiology of nerves and muscles
- Description of electrical excitation of nerve cells
- Electrical fields and electrochemical processes at electrodes
- Methods of selective nerve stimulation
- Effects of chronic electrical stimulation of nerve and muscle
- Limits of safe electrical stimulation
- System theory and control aspects in neural prosthetics
- Simulation of nerve excitation
- Design of stimulators for electrical stimulation
- Characteristic parameters for different applications in electrical stimulation.

The learning targets and objectives will be summarized at the end of each lecture and a comprehensive summary will take place at the end of the course to repeat the most important objectives and facilitate preparation of the oral examinations.

# Zu erbringende Prüfungsleistung / Examination result

written or oral examination

# Benotung / Grading

The module grade is calculated from the result of the final examination.

# Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

# Literatur / Literature

Actual copies of the slides will be delivered accompanying to the lectures.

Literature:

- Horch, K.W., Dhillon, G.S. (Hrsg.): Neuroprosthetics – Theory and Practice. (Series on Bioengineering & Biomedical Engineering – Vol. 2)
- River Edge: World Scientific Computing, 2004
## Modul / Module

**Mikrobiologische Grundlagen für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems**

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5406</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:

**2**

**ECTS-Punkte:**

**3**

**SWS:**

2 Lecture

**Angebotsfrequenz:**

Only in the summer term

**Arbeitsaufwand:**

90 hours

(28 Hours Full-time attendance course of study + 62 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Mikrosystemtechnik
    - Life Sciences: Biomedical Engineering
    - Life Sciences: Lab-on-a-chip
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Life Sciences: Biomedical Engineering
    - Life Sciences: Lab-on-a-chip
    - Personal Profile
  - Master of Science in Sustainable Systems Engineering
    - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

Understanding principle molecular biology processes used in technical systems for the analysis of biomolecules. The participant will understand methods such as DNA analysis (example PCR) and protein analysis (example ELISA) and will learn how to plan for the equipment and performance of such experiments.
### Inhalte Vorlesung / Content of the lecture

- DNA Analysis (Enzymes / Methods / Equipment)
- Different PCR methods
- DNA Fingerprinting
- Protein Analysis (Enzymes / Methods / Equipment)
- Antibody based detection (ELISA)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Materials will be provided through the ILIAS system. An ILIAS page will be generated prior to the start of the course and communicated to the students.
### Modul / Module

**Mikrosystemtechnik in der Medizin / Microsystems technology in Medicine**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5307</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. M. Boeker</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fakulty of Medicine</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Grundlegende physikalische Kenntnisse</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences; Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences; Biomedical engineering
  - Personal Profile

### Lernziele / Learning target

Wichtige Anwendungen der Mikrosystemtechnik in der Medizin beschreiben können:
- Computergestützte Bildanalyse
- Patch-Clamp Verfahren
- Klinische Anwendung beim Mammakarzinom
- Cochlea-Implantat
- Sehprothesen
- Diagnostik und Therapie von Herzrhythmusstörungen
- Volumetrische Bildgebung in der Radiologie

**Inhalte Vorlesung / Content of the lecture**

Dozenten aus verschiedenen Fachbereichen der Medizin stellen wichtige und aktuelle Themen der Mikrosystemtechnik in der Medizin vor: Sehprothesen, Cochlea-Implantate, minimal invasive Gefäßtherapien, computergestützte Tumordiagnostik, klinische Anwendungen beim Brustkrebs, Diagnostik und Therapie von Herzrhythmusstörungen und Verfahren der Bildanalyse in der bildgebenden Diagnostik. Dabei stellen die Dozenten insbesondere eine Verbindung zwischen den medizinisch-biologischen Gegebenheiten im menschlichen Organismus und der technischen Herangehensweise an ein spezifisches medizinisches Problem her, ohne dass besondere medizinische Kenntnisse vorausgesetzt werden.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Nanobiotechnologie / Nanobiotechnology

Nummer: Number
11LE50MO-5308

Modulverantwortlicher: Responsible person
Prof. Dr. O. Ambacher

Einrichtung: Organisational unit
Chair for Compound Semiconductor Microsystems

Modultyp: Module Type
Elective Module

Modulmodul: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
German

Empfohlenes Fachsemester:: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendungbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target


Inhalte Vorlesung / Content of the lecture

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Benotung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
- Physiologie des Menschen, R.F. Schmidt, F. Lang, G. Thews, Springer Medizin Verlag Heidelberg 2005

### Modul / Module

**Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in Applications: Environmental Aspects and Nanotoxicity**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5318</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td>(32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The aim is to learn what nanomaterials are and where they are utilized. Especially differences to bulk materials in context of utilization and toxicity will be discussed. The students should be able after the course to contribute in public discussions about "nanotoxicity" and "nanomaterials" a scientific viewpoint and balanced opinion. Furthermore the lecture should stimulate the scientific potential as well as the awareness of risks of nanomaterials in future research efforts of the students in the framework of Bachelor, Master
and PhD theses.

**Inhalte Vorlesung / Content of the lecture**

- Introduction to nanomaterials and aspects of toxicity
- Applications of colloidal metal and semiconductor nanoparticles
- Applications of nanocarbon compounds
- Applications of other nano(composite) and nanohybrid materials
- Nanomaterial drugs and drug carrier systems
- Environmental aspect of (nano)materials
- Interaction of nanomaterials with organism; Uptake and fate of nanomaterials
- Nanotoxicity legislation aspects

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Neurophysiologie – Laboratory / Neurophysiology - Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5316</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Hofmann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Faculty of Medicine</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Prerequisite to become eligible for this course is the participation in the exercises in &quot;Implant manufacturing technologies&quot; or participation in the seminar „Neuroprosthetics“ in the last winter semester.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Participants will gain first hand experiences into neuroscientific and electrophysiologically verifiable paradigms to natural signal processing in the rat brain in vivo. Participants will get in depth insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat’s learning and orientation system will be introduced in depth as well. Signal processing methods will be presented and for later use in exercises substantiated. Participants will learn a respectful and honorable handling of living beings, even if they are „only“ lab rats. Students will gain first hand experience with multisite electrophysiological recordings from
anesthetized and freely moving animals. Signals acquired during these day long experiments will be analyzed according to state of the art and results will be presented as reports and talks.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will in three neurophysiological paradigms (two acute, one freely behaving) under experienced supervision participate. Students will get in depth and first hand insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat's learning and orientation system will be introduced as well. Signal processing methods will be presented and for later use in exercises substantiated. They will gain hands on experience with in vivo animal electrophysiology with micro devices and collect data for subsequent home based analysis. Their analysis results will be presented as final teaching experience.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written reports and presentation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The final module grade is calculated from the tests during the experiments (1/3) plus the grade from the oral presentation (2/3).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
Neuroprosthetics is an emergent field of biomedical engineering aiming at developing devices to replace or augment non-functional sensory or motor pathways of humans resulting from disease or trauma. The participating student will be instructed on the basic neuromedical concepts, and the targeted medical deficits, both needed to evaluate current clinical neuroprotheses and critically assess devices under development.
The student will gain well-funded knowledge on clinical applications and technologies and will have to face the more biological and ethical aspects of these devices and treatment options as well. The module aims at active involvement by independent web-based information acquisition, oral presentation of findings, and internet-based reporting.

### Inhalte Vorlesung / Content of the lecture

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson’s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

### Zu erbringende Prüfungsleistung / Examination result

- 40% on the presentation
- 40% on the topic website
- 20% active involvement

### Benotung / Grading

The final module grade is calculated 40% on the presentation, 40% on the topic website and 20% active involvement.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE</td>
</tr>
</tbody>
</table>
Modul / Module

Neurowissenschaften für Ingenieure / Neuroscience for Engineers

Nummer: Number 11LE50MO-5319

Modulverantwortlicher: Responsible person Prof. Dr. U. Egert
Einrichtung: Organisational unit Chair for Biomicrotechnology

Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study 2
ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 lecture + 1 exercises
Angebotsfrequenz: Regular cycle Only in the summer term
Arbeitsaufwand: Workload 90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

Lernziele / Learning target

The aim of this module is to convey an understanding of fundamental neuroscientific concepts, methods, processes and structures that define or influence the function of technical components in biomedical applications.

Inhalte Vorlesung / Content of the lecture

The lecture series conveys the foundations of various neuroscientific processes, structures and measuring techniques.
We emphasize processes that

- influence the generation and properties of signals measurable with neuronal systems,
- influence the usability of MST components, such as sensors and implants,
- are relevant for typical fields of application of MST components, e.g. implantable sensors, prostheses, neurotechnology, etc..

In the course of the lectures we will present and overview of central neuroscientific concepts, tools and applications

Main topics are:

- Structure of the nervous systems
- Biophysics of electrical potentials
- Neuronal networks and their signals
- Sensory systems
- Foundations of learning and memory
- Interaction with neuronal networks

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Literature will be presented during the lecture
## Oberflächenanalyse – Laboratory / Surface Analysis Laboratory

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oberflächenanalyse – Laboratory / Surface Analysis Laboratory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5311</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

### Lernziele / Learning target

Microsystems – especially those for microfluidics – are dominated by their surfaces due to their surface to volume ratio. This strong influence of surfaces is also important for devices e.g. sensors that are in contact with biological fluids. Surface analytical methods are, hence, often at the center of research questions in microsystems engineering. The Surface Analysis Laboratory introduces selected methods in this field and discusses strengths and limitations of each technique. It concentrates on surface analytical questions which are relevant for the life sciences.
Inhalte Praktikum / Content of the laboratory

Topic 1: Determination of the layer thickness and roughness of biocompatible coatings
Experiment 1: Using ellipsometry and x-ray reflectometry to determine the thickness of hydrogel coatings

Topic 2: Wetting of surfaces – Surface free energies
Experiment 2: Measurement of the contact angles of test liquids in various surfaces; Determination of the surface free energy using the Zisman method
Experiment 3: Generation and characterization of microarrays on various surfaces

Topic 3: Proteins / peptides on surfaces
Experiment 4: Measurement of the adsorption of blood proteins on surfaces using Surface Plasmon Resonance
Experiment 5: Characterization of the structure of protein layers using Fourier Transform Infrared Spectroscopy

Topic 4: DNA at surfaces
Experiment 6: Visualisation of DNA on mica using the Atomic Force Microscope

Zu erbringende Prüfungsleistung / Examination result

Before each experiment there will be an oral examination and for each experiment the student has to submit a written laboratory report.

Benotung / Grading

The module grade will be determined from the average of the grades of the oral examinations and the laboratory reports.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- Lecture notes.
Modulhandbuch M.Sc. Mikrosystemtechnik – Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals

Modul / Module

Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study | 2 |
ECTS-Punkte: ECTS-points | 6 |
SWS: Semester week hours | 2 Lecture |
Angebotsfrequenz: Regular cycle | Only in the summer term |
Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

The objective of the module is to show, how signal processing and analysis methods can add additional information to the classical ways of interpreting brain signals measured by electroencephalography (EEG) or magnetoencephalography (MEG). This goes beyond the basic signal processing methods to separate the signal from background noise. General techniques for pattern recognition will be presented and how they are tailored for the daily use in clinical practice or neuroscience research. As a result students will have knowledge of general tools in pattern recognition in recordings of brain signals and how to adapt them to the requirements of the specifics needs in clinical use or for research projects.
The second part of the module will add modelling to the signal analysis to perform the localization of generators of brain activity. Different approaches of modelling of the head and the generators of the brain activity will be introduced. The objective is to provide the students with knowledge about different modelling levels and strategies about the selection of generator models, which are appropriate for a given source localization task.

Inhalte Vorlesung / Content of the lecture

The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies.

a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously.
b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy.
c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic.

In detail following strategies will be presented:

a) Heuristics
b) Template matching
c) Wavelet transformation
d) Hilbert transformation
e) Background and target modelling
f) Artificial neural networks

A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements. The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the forward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented:

a) Spherical model
b) Boundary element model
c) Finite element model

Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination
**Benuung / Grading**

The module grade is calculated from the result of the final examination.

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
# Module

## Technologien der Implantatfertigung / Implant Manufacturing Technologies

<table>
<thead>
<tr>
<th><strong>Number</strong></th>
<th>11LE50MO-5313</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher</strong>&lt;br&gt;* Responsible person*</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td><strong>Einrichtung</strong>&lt;br&gt;* Organisational unit*</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td><strong>Modultyp</strong>&lt;br&gt;* Module Type*</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer</strong>&lt;br&gt;* Module duration*</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen</strong>&lt;br&gt;* Connected events*</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache</strong>&lt;br&gt;* Language*</td>
<td>English</td>
</tr>
</tbody>
</table>

| **Fachsemester**<br>* Recommended term of study* | 3 |
| **ECTS-Punkte**<br>* ECTS-points* | 3 |
| **SWS**<br>* Semester week hours* | 2 lecture + 1 exercises |
| **Angebotsfrequenz**<br>* Regular cycle* | Only in the winter term |

| **Arbeitsaufwand**<br>* Workload* | 90 hours |
|  | (42 Hours Full-time attendance course of study + 48 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

## Lernziele / Learning target

Learning target and scientific objective of the module is to impart the physical and technological basics to design, develop and manufacture active implantable medical devices including basic structures and elements as well as methods and processes. The lecture lays the theoretical engineering basis to understand function and failure modes in active implantable medical devices. It teaches the students the different fundamental processes with which complex implants can be realised. The accompanying exercise complements the theoretical knowledge and adds practical aspects and guides the students to independently apply the acquired knowledge.
### Inhalte Vorlesung / Content of the lecture

The lecture „implant manufacturing technologies“ teaches knowledge and methods to develop electrically active medical devices, e.g. cardiac pacemakers and cochlea implants. Materials, components, systems, legal requirements are covered in the lecture. Clinically established neural implants as well as latest research applications will be presented and discussed. The following topics will be covered within this course:

- Overview of active implants and neural prostheses in clinical application and research
- Definition and classification of electrical active implants
- Biocompatibility (definition and tests) and Biostability (corrosion and degradation)
- Electrodes
- Concepts of active implants (components, interfaces)
- Silicone rubber as material for encapsulation
- Materials for hermetic packages
- Assembling and packaging technologies
- Legal Requirements (risk management, FMEA, clean rooms, documentation)
- Thin-film technology and implant manufacturing
- Manufacturing of an implant on the example of a BION

The learning targets will be summarized and discussed with the students at the end of every lecture and at the end of the course to facilitate preparation of the exams.

### Inhalte Übung / Content of the exercises

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade
of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modulhandbuch M.Sc. Mikrosystemtechnik – Technologien der Implantatfertigung – Laboratory / Implant Manufacturing Technologies - Laboratory

### Modul / Module

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5314</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

#### Zwingende Voraussetzungen: Mandatory preconditions
Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing technologies" in the last winter semester.

#### Empfohlene Voraussetzungen: Recommended preconditions
High school education in mathematics and natural sciences

#### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>Fachsemester: Recommended term of study</th>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

#### SWS: Semester week hours

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>Laboratory</th>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Laboratory</td>
<td></td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

#### Arbeitsaufwand: Workload

| Arbeitsaufwand: Workload | 90 hours (56 hours Full-time attendance course of study + 34 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

### Lernziele / Learning target

Objective of the module is the consolidation of the knowledge and the acquisition of skills to manufacture implants on the background of the theoretical knowledge gathered in the
The module teaches the students the application and combination of different technological processes to manufacture electrical active implantable devices under clean room conditions.

**Inhalte Praktikum / Content of the laboratory**

In the course of the practical exercises, the students re-build the first generation of a neuroprosthetic device, a cochlear implant. Groups with a maximum of three persons manufacture the implant in structured learning units on their own under supervision at different manufacturing setups. The learning units include:

- Laser marking and cutting
- Screen printing
- Hybrid implant assembly
- Design of printed circuit boards
- Development and etching of printed circuit boards
- Cleansing and cleaning of substrates
- Silicone encapsulation or electronic circuits
- Packaging and sterilization
- Technical implant function test

**Zu erbringende Prüfungsleistung / Examination result**

Written examination prior to every experiment

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

**Polymerchemie für Ingenieure / Polymer Chemistry for Engineers**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5399</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Chemistry and Physics of Interface</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Organic Chemistry for Microsystems Engineering</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>B.Sc. lectures in Chemistry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Irregular</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (56 hours Full-time attendance course of study + 34 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective module for students of following study programmes

- Master of Science im Fach Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science im Fach Mikrosystemtechnik
  - Life sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science im Fach Microsystems Engineering
  - Life sciences: Biomedical Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

This lecture will enable participants to understand how the molecular structure of polymers influences their properties. They will thus be able to choose the right polymer for their applications.
### Inhalte Vorlesung / Content of the laboratory

This lecture includes:

- Surface modifications, techniques and components
- Manufacturing biochips
- State of the art, an overview
- Nucleic acid based biochip analytics
- Protein biochip technologies
- Complex biochip applications

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Concentration-Area Microsystems Engineering –
Life sciences: Lab-on-a-chip

The Concentrations direction "Circuits and systems" is one of several Concentration
directions in the Master of Science in Microsystems Engineering.
Students who have chosen this direction, it must complete minimum 9 ECTS points in this
direction.

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biobrennstoffzelle und Bioelektrochemische Systeme / Biofuel Cells and Bioelectrochemical Systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5401-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

| Empfohlene Voraussetzungen: Recommended preconditions | High school education in mathematics and natural sciences |

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>4 oder 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>1 Lecture + 1 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand: Workload</th>
<th>90 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(28 oder 32 Hours Full-time attendance course of study + 58 oder 62 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture

In der Vorlesung wird eine Einführung in elektrochemische Energiewandler und speziell in bioelektrochemische Systeme gegeben. Behandelt werden schwerpunktmäßig die Punkte theoretischer Hintergrund und Funktions-Prinzipien, Design, Anwendungsbeispiele, und Methoden zur Charakterisierung.

### Inhalte Seminar / Content of the seminar

Im Seminar halten die Studierenden Vorträge zu aktuellen Themen aus den Bereichen Biobrennstoffzelle, Bioenergie und regenerative Energieversorgung. Im praktischen Teil werden Biobrennstoffzellen aufgebaut und elektrochemisch charakterisiert. Dieser Teil wird mit einer Auswertung und Diskussion der erhaltenen Ergebnisse abgeschlossen. Um zur Abschlussprüfung zugelassen zu werden, muss die schriftliche Ausarbeitung erfolgreich bestanden sein.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its
ECTS-points in the calculation of the overall grade.

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Lecture notes will be provided.
Biochiptechnologien / Biochip Technologies

Nummer: 11LE50MO-5402

Modulverantwortlicher: Prof. Dr. J. Rühe
Einrichtung: Chair for Chemistry and Physics of Interfaces

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture
Sprache: English

Empfohlenes Fachsemester: 4
ECTS-Punkte: 3

SWS: 2 Lecture
Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target

For modern Life sciences and molecular diagnostics Biochip technologies play a key role for miniaturization and parallelization of analysis. They combine different methods for microstructuring surfaces, for immobilizing biomolecules and read-out technologies. Here, all the aspects and tools for the development of modern bioanalytical surfaces and applications will be addressed in this lecture.

Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Surface modifications, techniques and components
- Manufacturing biochips
- State of the art, an overview
- Nucleic acid based biochip analytics
- Protein biochip technologies

**Complex biochip applications**

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various materials are available on the website <a href="http://www.cpi.uni-freiburg.de/">http://www.cpi.uni-freiburg.de/</a></td>
</tr>
</tbody>
</table>
### BioMEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
Knowledge in „Sensors“ or „Sensors and actuators“

**Empfohlenes Fachsemester:: Recommended term of study**
2

**ECTS-Punkte: ECTS-points**
3

**SWS: Semester week hours**
1 Lecture

**Angebotsfrequenz: Regular cycle**
Only in the summer term

**Arbeitsaufwand: Workload**
90 hours
(14 Hours Full-time attendance course of study + 76 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - MEMS Processing
  - Personal Profile

**Lernziele / Learning target**
The students will obtain knowledge in different topics of microsystems comprising biological components as well as microsystems for biological applications. They will obtain a profound understanding of the underlying biological and microsystems concepts by several selected examples. The final learning objective is the understanding of connections between biology, biochemistry, microfluidics, medicine and micro engineering as well as the application of this understanding to future topics in this field.
**Inhalte Vorlesung / Content of the lecture**

- Introduction
- Biochemistry and cells
- Cell culture monitoring
- Tissue engineering and cell handling
- Cell mechanics
- Single cell analysis
- Sensors based on microorganism
- Immunoassays and immunosensors
- DNA and RNA analytics on chip
- Implantable devices, in vivo sensors
- “Wellness MEMS”

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Biotechnologie für Ingenieure I: Einführung, Molekular- und Mikrobiologie (früher: BioMST 1 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik) / Biotechnology for Engineers I: Introduction, Molecular- and Microbiology (former: BioMST 1 – Biotechnological Tasks for Microsystems Technology)

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5315</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. Felix von Stetten</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Chair MEMS Applications</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Moduldauser Module duration</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td>(56 oder 64 hours Full-time attendance course of study + 116 oder 124 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Microsystems Engineering
  - Information Systems
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Sustainable Materials

### Lernziele / Learning target
The students know the spectrum of biotechnology and have an understanding of micro- and molecular biological basics and methods. They are able to apply fundamental laboratory methods and to interpret the experimental results. Students are able to assess in which areas of micro- and molecular biology the use of microsystem technology enables future improvements.

### Inhalte Vorlesung / Content of the lecture

- Spectrum of biotechnology
- Basics of micro- and molecular biology
- Laboratory instrumentation and automation
- Microbiological methods
- Molecular biological methods
- Methods for genome sequencing

### Inhalte Praktikum / Content of the laboratory

- Preparation of nutrient media
- Bacterial culture
- Determination of bacterial count
- DNA extraction from bacteria
- DNA quantitation by real-time PCR
- Detection of bacteria by Immunoassay
- Assay automation by lab-on-a-chip technology

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Participation in the lab-course requires that the examination of the lecture has been passed.

### Zu erbringende Studienleistung / Course Achievement

Completion of the module requires a passed examination of the lecture and a successful participation in the laboratory course (presentation, written lab report)

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Lecture notes will be provided.

Additional reading material in German:  
- Biotechnologie für Einsteiger, R. Renneberg, u.a., Spektrum Akademischer Verlag  
- Taschenatlas der Biotechnologie und Gentechnik, R. D. Schmid, Wiley-VCH  
- Taschenatlas der Biochemie, Jan Koolmann, u.a., Thieme
### Modul / Module

**Biotechnologie II für Ingenieure: Bioprozesstechnik, Lebensmittelanalytik und in-vitro Diagnostik**  
(früher: BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / Biotechnology for Engineers II: Bioprocess engineering, food analysis and in-vitro diagnostics)  
(former: BioMST 2 – Biotechnological Tasks for Microsystems Technology)

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5317</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher: Responsible person</strong></td>
<td>PD Dr. Felix von Stetten</td>
</tr>
<tr>
<td><strong>Einrichtung: Organisational unit</strong></td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td><strong>Modultyp: Module Type</strong></td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer Module duration</strong></td>
<td>2 terms</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen: Connected events</strong></td>
<td>Lecture and laboratory</td>
</tr>
<tr>
<td><strong>Sprache: Language</strong></td>
<td>German or English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECTS-Punkte: ECTS-points</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>SWS: Semester week hours</strong></td>
<td>2 lecture + 2 for laboratory</td>
</tr>
<tr>
<td><strong>Angebotsfrequenz: Regular cycle</strong></td>
<td>Only in the winter term</td>
</tr>
<tr>
<td><strong>Arbeitsaufwand: Workload</strong></td>
<td>90 hours</td>
</tr>
<tr>
<td></td>
<td>(32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
  - Information Systems
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Sustainable Materials
Lernziele / Learning target

The students know the basics of bioprocess engineering for the production of pharmaceutical drugs and fermented foods. They have an understanding of the layout and function of bioreactors and understand important up- and down-stream processes. Furthermore, the students are familiar with important microbial foodborn and human pathogens and understand how these can be detected by micro- and molecular biological methods. Practical insight is obtained through excursions to companies in the fields of pharmaceuticals, in-vitro diagnostics, food-biotechnology and -analytics. Students are able to assess in which areas of bioprocess engineering and in-vitro diagnostics the use of microsystem technology enables future improvements.

Inhalte Vorlesung / Content of the lecture

Bioprocess engineering
- Layout and function of bioreactors
- Measurement technology for bioreactors
- Up-stream processing
- Fermentation
- Down-stream processing
Food analysis and in-vitro diagnostics
- Market analysis
- Pathogenic microorganisms
- Microbiological diagnostics
- Immun- and nucleic acid diagnostics
- Potential of microsystem technology

Inhalte Prakikum/Exkursion / Content of the lab/excursion

Excursions to
- Pharmaceutical company
- In-vitro diagnostics manufacturer
- Medical centralized laboratory
- Food biotechnology company

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

Completion of the module requires a passed examination of the lecture and a successful participation at the excursion (company presentation, written report)

Benotung / Grading

The module grade is calculated from the result of the final examination.
### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Lecture notes will be provided.

Additional reading material in German:
- Biotechnologie für Einsteiger, R. Renneberg, u.a., Spektrum Akademischer Verlag
- Taschenatlas der Biotechnologie und Gentechnik, Rolf D. Schmid, Wiley-VCH
**Modul / Module**

**DNA Analytik / DNA Analysis**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5404</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisation unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - Master of Science in Embedded Systems Engineering
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Life sciences: Lab-on-a-chip
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Life sciences: Lab-on-a-chip
    - Personal Profile

**Lernziele / Learning target**

The key principles of DNA analysis are taught using standard and high tech applications to demonstrate the underlying mechanisms of DNA analysis. Starting with the biochemical role of the DNA the principles of enzymatic modification and physical detection of nucleic acids are covered. PCR is used as a demo application to introduce the key features of DNA analysis. From there on the areas of sequencing and DNA microarrays are covered as well as the use of databases to gain information about DNA sequences and how to design DNA primers and probes. The technical equipment to perform PCR, gel electrophoresis, microarray production and readout is also addressed. The lecture should give the student the theoretical background to understand, plan and perform DNA analysis research.
### Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Structure and function of DNA
- Enzymes that process DNA
- DNA amplification (PCR)
- DNA detection (gel electrophoresis, ...)
- Application in forensic sciences
- DNA microarray overview

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Various materials are available on the website http://www.cpi.uni-freiburg.de/
## Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5407</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td>(28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

Biochip technologies play a key role in the miniaturization and parallelization of bioanalytical techniques. They combine microbiological methods with microsystems engineering. The students will understand the requirements for the integration of modern bioanalytical methods in miniaturized devices. Special emphasis will be given to bioanalytical surfaces and surface architectures and the students will learn how to apply such concepts to chip-based bioanalytical assays.
<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
</table>
| • Interaction of surfaces with biological environments  
| • Design criteria for bioanalytical surfaces and interfaces  
| • Procedures and techniques for biochip fabrication  
| • Nucleic acid based biochips  
| • Protein biochip technologies  
| • Complex biochip applications |

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
</table>
| • Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
| • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
| • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. |

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials will be provided through the ILIAS system. An ILIAS page will be generated prior to the start of the course and communicated to the students.</td>
</tr>
</tbody>
</table>
## Module

**Mikrobiologische Grundlagen für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5406</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachsemester:** Recommended term of study | 2 |
| **ECTS-Punkte:** ECTS-points | 3 |
| **SWS:** Semester week hours | 2 Lecture |
| **Angebotsfrequenz:** Regular cycle | Only in the summer term |
| **Arbeitsaufwand:** Workload | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

## Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

## Learning target

Understanding principle molecular biology processes used in technical systems for the analysis of biomolecules. The participant will understand methods such as DNA analysis (example PCR) and protein analysis (example ELISA) and will learn how to plan for the equipment and performance of such experiments.
### Inhalte Vorlesung / Content of the lecture

- DNA Analysis (Enzymes / Methods / Equipment)
- Different PCR methods
- DNA Fingerprinting
- Protein Analysis (Enzymes / Methods / Equipment)
- Antibody based detection (ELISA)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Materials will be provided through the ILIAS system. An ILIAS page will be generated prior to the start of the course and communicated to the students.
Modul / Module

Mikrofluidik II: Mikrofluidische Plattformen / Microfluidics II: Platforms

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5405</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Micro-fluidics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target


Insgesamt soll der Student erkennen welche Potentiale, aber auch Limitierungen, die Mikrofluidik und deren Anwendung im Bereich der Lebenswissenschaften besitzt. Und dass man sich generell hier in einem noch nicht fest etablierten Feld befindet, wo es noch viele
In der ersten Stunde wird zunächst definiert was eine „mikrofluidische Plattform“ (µFP) (1 Doppelstunde) überhaupt ist und dann ein Überblick über etablierte µFP gegeben. Danach werden der Reihe nach folgende µFP im Detail erläutert und ein Ausblick auf Neuentwicklungen oder Entwicklungspotential gegeben.


Kapillar getriebene µFP (1 Doppelstunde) bewegen Flüssigkeiten mittels Kapillarkräfte und sind wohl die ältesten Anwendungen in Form des allseits bekannten „Schwangerschaftstests“. Es werden der Aufbau und die Möglichkeiten zur Diagnostik dieser Systeme aufgezeigt. Zusätzlich wird erklärt, wie genau ein Immuno-Assay abläuft (ebenso ein ELISA) und welche Reagenzien im System enthalten sind.

Druckgetriebene µFP (2 Doppelstunden) erlaubten die Aktuation der Flüssigkeiten mittels Druckunterschiede. Zunächst werden unterschiedliche Systeme zur Herstellung dieser Druckdifferenz, sowie die Vor- und Nachteile vorgestellt. Aktuelle Anwendungen wie Partikeltrennung, Diagnostik-anwendungen (Herzinfarktschnelltest, Probenaufreinigung und PCR) bis hin zur „Large Scale Fluidik Integration“ als Analogie zur Mikroelektronik werden dann detailliert besprochen. Zusätzlich wird erklärt wie man mittels PCR Gensequenzen amplifizieren und detektieren kann.

Bei Zentrifugale µFP (2 Doppelstunden) nutzt man neben der Zentrifugalkraft auch Euler-Coriolis- und Kapillardrucke zur Prozessierung und Verschaltung von Flüssigkeiten. Eigene im Chair entwickelte und weitere Anwendungen dieser Plattform wird dann am Beispiel von Probenaufreinigung, GenoTyp / Typeisierung bis hin zu Immunoassay dargestellt.

Zusätzlich wird die Aufreinigung von DNA aus einer Probe erläutert.

Droplet based µFP (2 Doppelstunden) umfassen den Bereich der Fluidik bei denen einzelne Tröpfchen generiert und prozessiert werden. Hierfür kann man sowohl druckgetriebene Aktuation als auch Surface Acoustic Wave bis hin zu Electrowetting benutzen. Es werden die einzelnen Techniken vorgestellt und gegeneinander verglichen. Zusätzlich wird erklärt wie ein zellulärer Assay aufgebaut ist.

Elektrokinetische µFP (1 Doppelstunde) nutzen mehrere Effekte die durch elektrische Felder hervorgerufen werden. Hierunter fallen die Elektrophorese, die Elektroosmose und die Dielektrophorese. Zunächst werden jedoch die Grundlagen der Chromatographie erklärt um ein Verständnis für die Anwendungen wie Gelelektrophorese, 2D-Elektrophorese und Isoelektrische Fokussierung zu schaffen.

Free scalable non-contact dispensing µFP (1 Doppelstunde) beschäftigen sich mit dem Problem wie man kleinste Flüssigkeitsmengen dosieren und transferieren kann. Ein Auslegungsbeispiel ist der allseits bekannte Tintenstrahldrucker. Es werden Systeme im Detail erklärt, die hier am Chair als Dispensing Wellplate und die TopSpot technologie entwickelt wurden.

High sampling µFP (2 Doppelstunden) beschäftigen sich damit wie man einige hundert bis Millionen von Assays oder Analysen parallel durchführen kann. Hierunter fallen die Mikroarrays und die Entwicklung der Pikowellplatte aus der ursprünglichen Mikrotiterplatte bis hin zur Einzel-zell-Analyse. Zusätzlich wird erklärt wie und warum man chemische Bibliotheken herstellt und austestet.
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Students will receive lecture notes which will be updated on a regular basis.
Concentration-Area Microsystems Engineering – Materials
The Concentration direction "Materials" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

Modul / Module

Analyse- und Messmethoden für Dünnschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5117</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study
ECTS-Punkte: ECTS-points
5 3

SWS: Semester week hours
2 lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours
(32 Hours Full-time attendance course of study + 58 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile
### Lernziele / Learning target

The module gives an overview of all state-of-the-art measurement and analysis methods for thin films and nanoscopic structures. Special emphasis will be placed on the prospects and drawbacks of each method as well as on typical limits and potential measurement artifacts. Educational objective is to enable students to find a suitable and appropriate method to measure or detect a certain material property of interest.

### Inhalte Vorlesung / Content of the lecture

The treated measurement and analysis techniques include optical, electrical, chemical and structural methods which detect and probe material properties like morphology/shape, film thickness, crystallinity, chemical composition, trace impurities, bonding configurations, bandgap, etc. Namely methods like AFM, SEM / TEM, APT, SIMS, XPS, SE, PL, FTIR, Raman, XRD, C-V / I-V, RBS and many more will be dealt with.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Bioactive Polymer Surfaces

**Number:** 11LE50MO-5321  
**Valid since:** 02.09.2015

**Responsible person:** Prof. Dr. Rühe  
**Organisational unit:** Chair for Chemistry and Physics of Interfaces

**Module Type:** Elective Module  
**Module duration:** 1 term

**Connected events:** Lecture  
**Language:** English

**Recommended requirements:**  
- General knowledge of organic chemistry  
- General knowledge of macromolecular chemistry

**Recommended term of study:** 3 ECTS

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>Lecture</th>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Lecture</td>
<td></td>
<td>Only in the winter term</td>
</tr>
</tbody>
</table>

**Workload:** 90 hours  
(32 Hours Full-time attendance course of study + 58 Hours Self-study)

## Usability of the module

Elective Module for students of the study program  
- Master of Science in Embedded Systems Engineering  
  - Personal Profile  
- Master of Science in Mikrosystemtechnik  
  - Life Sciences: Biomedical Engineering  
  - Materials  
  - Personal Profile  
- Master of Science in Microsystems Engineering  
  - Life Sciences: Biomedical Engineering  
  - Materials  
  - Personal Profile

## Learning target

The aim of this module is to enable you to  
- understand the basic physical properties of polymer surfaces  
- get to know fabrication processes of polymer surfaces  
- understand different kinds of bioactivity, their mechanisms, and their applications  
- understand the interaction of polymer surfaces with organisms
### Inhalte Vorlesung / Content of the lecture

- Surface properties
- Synthesis of functional polymer surfaces: non-covalent and covalent attachment, coating of surfaces with polymers, microstructuring of polymer surfaces
- Interaction of polymer surfaces with biomolecules and cells
- Antimicrobial, protein-resistant and antifouling polymer surfaces, DNA immobilization on surfaces, DNA origami, immunoactive polymer surfaces, etc.
- Special applications

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Literature recommendations will be provided with the lecture material.
### Bioactive Polymer Surfaces with seminar

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5322</th>
<th>Gültig seid: Valid since</th>
<th>02.09.2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Rühe</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended requirements</td>
<td>- General knowledge of organic chemistry - General knowledge of macromolecular chemistry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 1 exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The aim of this module is to enable you to
- understand the basic physical properties of polymer surfaces
- get to know fabrication processes of polymer surfaces
- understand different kinds of bioactivity, their mechanisms, and their applications
- understand the interaction of polymer surfaces with organisms
• learn to work with original research papers

**Inhalte Vorlesung / Content of the lecture**

- Surface properties
- Synthesis of functional polymer surfaces: non-covalent and covalent attachment, coating of surfaces with polymers, microstructuring of polymer surfaces
- Interaction of polymer surfaces with biomolecules and cells
- Antimicrobial, protein-resistant and antifouling polymer surfaces, DNA immobilization on surfaces, DNA origami, immunoactive polymer surfaces, etc.
- Special applications

**Inhalte Übung / Content of the exercises**

In this exercise class, you will work with original research papers and write a short review of selected topics.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course achievement**

The tutorials help the students to get a more in depth and thorough understanding of the topic. Students will work with original research papers and have to write a short review of a selected topic which will be evaluated.

**Benoitung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Literature recommendations will be provided with the lecture material.
### Bioinspired functional materials

| Nummer: Number | 11LE50MO-5125 | Gültig seid: Valid since | 22.02.2017 |
| Modulverantwortlicher: Responsible person | Dr. Osorio-Madroza | Einrichtung: Organisational unit | Chair for Sensors |
| Modultyp: Module Type | Elective Module | Moduldauer Module duration | 1 term |
| Zugehörige Lehrveranstaltungen: Connected events | Lecture | Sprache: Language | German or English |
| Empfohlene Voraussetzungen: Recommended requirements | | | |

| Empfohlenes Fachsemester:: Recommended term of study | 2 | ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture | Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitaufwand: Workload | 900 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) | | |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

In this module the students will get fundamental knowledge on the structure and functionality of biological materials as to apply their design principle in the development of bioinspired biomaterials. At the end of the module, the student should be able to describe the interrelation between microstructure and properties in biological materials; apply advance methods for the characterization of microstructure and properties of biological and artificially developed bioinspired...
materials and explain the method theoretical principle; and describe the physico-
chemistry of the processing of different bioinspired materials studied in the course.

Inhalte Vorlesung / Content of the lecture

- Organic-based biological materials. Hierarchical structure and functionality
- Mineralized biological materials. Hierarchical structure and functionality
- Advanced methods to characterize the microstructure and properties of biological
  and bioinspired materials (Materials physical-chemistry and materials physics:
  mechanical testings; scattering techniques SAXS and WAXS for microstructure
  characterization; spectroscopic techniques for chemical structure characterization).
  Establishment of structure-properties relationship in biomaterials
- Examples of preparation methods of bioinspired materials. Processing physical-
  chemistry and optimization
- Interrelation between processing, structure and properties in bioinspired materials
- Examples of bioinspired materials for technological and biomedical applications

Inhalte Übung / Content of the exercises

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course achievement

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The
  grade of the module is single-weighted according to the number of its ECTS-points in the
  calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of
  the module is single-weighted according to the number of its ECTS-points in the calculation
  of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the
  module is single-weighted according to the number of its ECTS-points in the calculation
  of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The
  grade of the module is single-weighted according to the number of its ECTS-points in the
  calculation of the overall grade.

Literatur / Literature
Modul / Module

Elektrochemische Energieanwendungen / Electrochemical energy applications

Nummer: Number 11LE50MO-5123  Gültig seit: Valid since 01.04.2016

Modulverantwortlicher: Responsible person Prof. Dr. R. Zengerle
Einrichtung: Organisational unit Chair for MEMS Applications

Modultyp: Module Type Elective module
Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language German or English

Empfohlenes Fachsemester:: Recommended term of study 2 ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Lectures + 1 Exercises Angebotsfrequenz: Regular cycle Irregular

Arbeitsaufwand: Workload 90 hours (42 hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Mikrosystemtechnik
  o Materials
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Materials
  o Personal Profile

Lernziele / Learning target
The students have acquired an understanding of the relevance of electrochemical systems for the global energy transition. They are able to transfer basic electrochemical effects to different electrochemical systems. They understand the connections between electrochemical analysis methods and properties of the considered electrochemical systems. They are able to propose simple strategies for the improvement of electrochemical systems.
### Inhalte Vorlesung / Content of the lecture

Electrochemical systems such as fuel cells, batteries or electrolysis cells are promising approaches for the global energy transition. Based on these examplaric electrochemical systems key electrochemical effects are taught in this course. Additionally partial thematic topics of the global energy transition such as electromobility or energy storage are discussed. Limitations and novel developments of the mentioned electrochemical systems are covered. Finally all important electrochemical characterisations methods are discussed and explained.

### Inhalte Übung / Content of the exercises

Within the exercises the topics of the lecture are reviewed deeply and complementary knowledge is taught.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Will be provided within the lecture.
Modulhandbuch M.Sc. Mikrosystemtechnik – Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers

Modul / Module

Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5719</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study

| 3 |
| 6 |
| ECTS-Punkte: ECTS-points |

SWS: Semester week hours

| 2 Lecture |
| 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

The students know the essential concepts and fundamental equations of electrochemical theory. The participants from different subjects link together the knowledge from physical chemistry and several engineering disciplines to get a sound understanding of the classical electrochemical methods and electrochemical impedance spectroscopy. The students can apply their knowledge and understanding of the electrochemical methods to tasks in the
field of material science, microtechnology, Microsystems and energy application.

### Inhalte Vorlesung / Content of the lecture

- Electrochemical theory (cells, electrodes, fundamental equation and concepts)
- Instrumentation (focus on the interplay between electrochemistry and electronics/data acquisition), equipment (electrodes, cells), and electrolytes
- Classical methods (potentiometry, amperometry, CV, DPV, SWV, HDME, RDE, RRDE)
- Electrochemical impedance spectroscopy (EIS)
- Selected aspects: Material science (corrosion, hierarchical micro-/nanostructures)
- Selected aspects: Microtechnology (electrodeposition, failure mechanism)
- Selected aspects: Microsystems (electrochemical sensors and actuators)
- Selected aspects: Energy application (fuel cells, batteries, super caps)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

**Modul / Module**

**Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5112</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystems Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in microsystems technology and semiconductor physics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

**Lernziele / Learning target**

This module provides a more detailed description of silicon technologies exceeding the modules in Microsystemtechnology I and II. The basics in silicon technologies will be accomplished by the most recent results found in literature.
Whenever possible, we will organize a visit of the Micronas GmbH in Freiburg and their CMOS Fab.

**Inhalte Vorlesung / Content of the lecture**

Substrate materials, oxidation, diffusion, implantation, polysilicon and epitaxy, silisides, metallisation, dielectric layers, SiGe, strained silicon, low- und high-k-dielectrics, photo lithography (immersion lithography, phase shift mask, EUV, chemical-mechanical polishing, process integration, CMOS-compatible micro mechanics)

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bemotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Chang/Sze: ULSI Technology, Wiley
- Semiconductor International: monatliche Technologie-Zeitschrift
Modul / Module

Halbleitertechnologie / Semiconductor Technology and Devices

Nummer: Number
11LE50MO-5108

Modulverantwortlicher: Responsible person
Prof. Dr. M. Zacharias

Einrichtung: Organisational unit
Chair for Nanotechnology

Modultyp: Module Type
Elective Module

Modulduer: Module duration
1 term

Zugehörige
Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlenes
Fachsemester: Recommended term of study
3

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours
(32 Hours Full-time attendance course of study + 58 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The module is specifically designed for the international master not familiar with Clean Room processes. It is a lecture which gives the basic knowledge in equipments and processes used in a Si Clean Room. In addition, the lesson will give an overview and some basic physics about typical devices like pn- junctions, solar cells, and photodetectors.

Inhalte Vorlesung / Content of the lecture

Mandatory knowledge for Si technology will be provided including wafer processing, wet and dry etching, CVD growth processes, doping, metallization, CMOS process, and others.
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Keramiktechnologie in der Mikrotechnik / Ceramic technology in microsystems

Modulverantwortlicher: Prof. Dr. T. Hanemann
Einrichtung: Chair for Materials Processing

Modultyp: Elective Module
Moduldauer: 1 term
Zugehörige Lehrveranstaltungen: Laboratory
Sprache: German

Empfohlene Voraussetzungen: Knowledge in "Keramische Werkstoffe der Mikrotechnik"

Empfohlenes Fachsemester: 2
ECTS-Punkte: 3
SWS: 2 Laboratory
Angebotsfrequenz: Only in the summer term
Arbeitsaufwand: 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target
Das Modul "Keramiktechnologie in der Mikrotechnik" hat das Ziel mit den Studenten "vom Pulver zur keramischen Mikrokomponente" den gesamten pulvertechno-logischen Herstellungsprozess von gesinterten Keramiken praktisch durch zu arbeiten. Das Modul dient dazu, die im Modul "Keramische Werkstoffe in der Mikrotechnik" behandelten Inhalte mit praktischen Experimenten zu veranschaulichen und ein vertieftes Verständnis für diese...
In der Mikrotechnik sehr wichtige Materialklasse zu wecken.

**Inhalte Praktikum / Content of the laboratoryecture**


**Zu erbringende Prüfungsleistung / Examination result**

graded protocols

**Benotung / Grading**

The final module grade is determined from an average of the grades of the individual reports.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Materials Processing</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

Ziel des Moduls ist es, die technologischen und physikalischen Grundlagen der keramischen Werkstoffe und die zugehörigen Prozessierungsmethoden zu vermitteln.
Mikrosystemtechnisch relevante Aspekte der keramischen Werkstoffe und ihrer Prozessierungsmethoden sollen aufgezeigt werden.

**Inhalte Vorlesung / Content of the lecture**


**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Begleitend zur Vorlesung wird ein Skriptum und werden Handzettel der Vorlesungsfolien zur Verfügung gestellt.
Modulhandbuch M.Sc. Mikrosystemtechnik – Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure

**Modul / Module**

**Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5121</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S. Hiermaier</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gips-Schuele-Chair of Sustainable Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

With this module Students are able to distinguish between damage and failure as two distinct process types in materials as other thermo-mechanic behaviors. Basic differences between phenomenological and physics based modeling approaches become evident. Specifically, the multi-scale character of the process is recognized. The resulting dimensions of related resources for computations as well as the necessity for scale-bridging methodologies is learnt. Furthermore, a variety of experimental and numerical methods for characterizing and modeling the processes is investigated.

**Inhalte Vorlesung / Content of the lecture**

To be announced.
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Kontinuumsmechanik I / Continuum mechanics I

<table>
<thead>
<tr>
<th><strong>Nummer</strong>: Number</th>
<th>11LE68MO-4301</th>
<th><strong>Gültig seid</strong>: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher</strong>: Responsible person</td>
<td></td>
<td><strong>Einrichtung</strong>: Organisational unit</td>
<td>Department of Sustainable Systems Engineering</td>
</tr>
<tr>
<td><strong>Modultyp</strong>: Module Type</td>
<td>Elective module</td>
<td><strong>Moduldauer</strong>: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen</strong>: Connected events</td>
<td>Lecture</td>
<td><strong>Sprache</strong>: Language</td>
<td>German or English</td>
</tr>
<tr>
<td><strong>Empfohlenes Fachsemester</strong>: Recommended term of study</td>
<td>3</td>
<td><strong>ECTS-Punkte</strong>: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td><strong>SWS</strong>: Semester week hours</td>
<td>2 Lecture</td>
<td><strong>Angebotsfrequenz</strong>: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td><strong>Arbeitsaufwand</strong>: Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

## Lernziele / Learning target

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics.

## Inhalte Vorlesung / Content of the lecture

- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic structure of continuum mechanics (kinematics, balance
equations, constitutive relations). The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017</td>
</tr>
<tr>
<td>• M. Itskov, Tensor Algebra and Tensor Analysis for Engineers, Springer, 2013</td>
</tr>
</tbody>
</table>
Modulhandbuch M.Sc. Mikrosystemtechnik – Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

**Modul / Module**

**Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4302</th>
<th>Gültig seid: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Kontinuumsmechanik I mit Übung</td>
<td>Einrichtung: Organisational unit</td>
<td>Department of Sustainable Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 2 exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (64 hours Full-time attendance course of study + 116 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

**Lernziele / Learning target**

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics.

The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

**Inhalte Vorlesung / Content of the lecture**

- Mathematical foundations of continuum mechanics (specialized to orthonormal base
systems) consisting of tensor algebra and tensor analysis

- Introduction to the basic structure of continuum mechanics (kinematics, balance equations, constitutive relations).

The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

### Inhalte Übung / Content of the exercises

The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
## Kontinuumsmechanik II / Continuum mechanics II

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4303</th>
<th>Gültig seit: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td></td>
<td>Einrichtung: Organisational unit</td>
<td>Department of Sustainable Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | • Kontinuumsmechanik I / Continuum mechanics I  
• Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises |
| Empfohlenes Fachsemester:: Recommended term of study | 3 | ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture | Angebotsfrequenz: Regular cycle | Only in winter term |
| Arbeitsaufwand: Workload | 90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

## Lernziele / Learning target

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics.

## Inhalte Vorlesung / Content of the lecture
• Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization
• Balance relations of mechanics and thermomechanics
• Principles of mechanics: principle of D'Alembert, principle of virtual displacements
• Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)
• Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Bebotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

• D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
• P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002
Modulhandbuch M.Sc. Mikrosystemtechnik – Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises

Modul / Module

Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises

Nummer: Number 11LE68MO-4304  Gültig seid: Valid since 01.10.2016

Modulverantwortlicher: Responsible person
Einrichtung: Organisational unit
Department of Sustainable Systems Engineering

Modultyp: Module Type Elective module  Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture
Sprache: Language  German or English

Empfohlene Voraussetzungen: Recommended prerequisites
- Kontinuumsmechanik I / Continuum mechanics I
- Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

Empfohlenes Fachsemester:: Recommended term of study 3  ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Lecture  Angebotsfrequenz: Regular cycle Only in winter term

Arbeitsaufwand: Workload 90 hours  (32 hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / Learning target

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.
<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization</td>
</tr>
<tr>
<td>• Balance relations of mechanics and thermomechanics</td>
</tr>
<tr>
<td>• Principles of mechanics: principle of D’Alembert, principle of virtual displacements</td>
</tr>
<tr>
<td>• Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)</td>
</tr>
<tr>
<td>• Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017</td>
</tr>
<tr>
<td>• P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002</td>
</tr>
</tbody>
</table>
Modul / Module

Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5115</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Eberl</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

The goal is to learn how materials properties and their impact on functionality and performance of micro systems. You will learn about the physical mechanisms in structural and functional materials as well as damage evolution during the applications lifetime. Based on the physical understanding you can evaluate microsystem designs, improve their lifetime and performance. This allows specifying materials and systems closer to their performance limit.
### Inhalte Vorlesung / Content of the lecture

Introduction: physical mechanisms  
Fundamentals in stress and strain as well as anisotropic properties  
Fundamentals in mechanics of beams and membranes explained in examples  
Micro- and nanostructured materials in micro systems  
Small scale characterization of mechanical properties  
- Intrinsic stresses  
- Elastic and plastic behavior  
- Adhesion properties  
Physical principles and loading conditions in functional materials for actors and sensors

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- L.B. Freund and S. Suresh: „Thin Film Materials“  
**Modulhandbuch M.Sc. Mikrosystemtechnik – Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components**

### Modul / Module

**Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5604</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Materials Processing</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaurer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

### Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

### Learning target

Besides silicon and the established MEMS/MOEMS technology polymer materials and the related microreplication technologies are becoming more and more important for the realization and commercial success of new microcomponents and microsystems. New nanostructuring methods like 2-photon-stereolithography and others are at the threshold of leaving the laboratory status and entering market. The course will cover the large variety of polymer materials, their fundamental chemical and physical properties and the derived microstructuring and replication possibilities. Direct and indirect micro- and nanostructuring
methods like deep X-ray lithography, stereolithography, laser machining, nanoimprinting and others as well as the large family of replication methods like hot embossing and injection molding will be described in detail. Master and tooling fabrication methods like electroplating, electro discharge machining as well as mechanical and laser micromachining will be presented and discussed intensely. A large number of application examples and case studies dealing with the accessible geometries, feasibility, and process characteristics will be used for the presentation of the polymer microfabrication importance.

Inhalte Vorlesung / Content of the lecture

Contents:
- Polymers: Fundamental chemical and physical properties
- Fabrication of molding tools: Fabrication principles and characteristics
- Rapid Prototyping in microsystem technology
- Polymer replication techniques: Reaction Molding, UV-Embossing, Hot Embossing and Injection Molding: Principles, equipment, applications and case studies
- From micro to nano: Nanoimprinting, soft lithography, nanostereolothography and other new developments

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Modulhandbuch M.Sc. Mikrosystemtechnik – Nanomaterialien / Nanomaterials

Modul / Module

Nanomaterialien / Nanomaterials

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5104</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Eberl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basiswissen in Festkörperphysik</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

Understanding of Concepts of nanomaterials preparation (chemical synthesis, cluster ripening, bottom-up approaches, nanowire growth, ...). This will be connected with the understanding of concepts of nanomaterial characterization. Advantages and risk of surfaces, surface functionalization, and nano-bio, nano-medical, nano-fluidic
### Inhalte Vorlesung / Content of the lecture

- Introduction size effects
- Concept of nano diagnostics
- High resolution methods for materials characterization
- Silica spheres and nano-gold
- Colloidal nanoparticles
- Si nanowire/ZnO nanowires
- Functionalization of surfaces Si nanocrystals
- Nanobiologic systems
- Nanomedicine systems

Nanofluidic

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Modul / Module

### Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in Applications: Environmental Aspects and Nanotoxicity

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5318</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The aim is to learn what nanomaterials are and where they are utilized. Especially differences to bulk materials in context of utilization and toxicity will be discussed. The students should be able after the course to contribute in public discussions about "nanotoxicity" and "nanomaterials" a scientific viewpoint and balanced opinion. Furthermore the lecture should stimulate the scientific potential as well as the awareness of risks of nanomaterials in future research efforts of the students in the framework of Bachelor, Master
and PhD theses.

**Inhalte Vorlesung / Content of the lecture**

- Introduction to nanomaterials and aspects of toxicity
- Applications of colloidal metal and semiconductor nanoparticles
- Applications of nanocarbon compounds
- Applications of other nano(composite) and nanohybrid materials
- Nanomaterial drugs and drug carrier systems
- Environmental aspect of (nano)materials
- Interaction of nanomaterials with organism; Uptake and fate of nanomaterials
- Nanotoxicity legislation aspects

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Module / Module

**Nano – Laboratory / Nano - Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Students must have passed either the module Nanomaterials or the module Nanotechnology.

**Empfohlenes Fachsemester: Recommended term of study**

<table>
<thead>
<tr>
<th></th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
</tbody>
</table>

**SWS: Semester week hours**

<table>
<thead>
<tr>
<th></th>
<th>2 Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

Fabrication and characterization of nanostructures (quantum dots, ultrathin layers, nanowires)

**Inhalte Praktikum / Content of the laboratory**
Fabrication and photoluminescence of Si nanocrystals
Fabrication and analysis (4PP, PL, SEM) of ALD ZnO thin films
Fabrication and analysis (PL, SEM) of metal oxide nanowires

**Zu erbringende Prüfungsleistung** / Examination result

1. Presentation and oral exam at the end of the lab course.

**Bewertung** / Grading

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung** / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Nanotechnologie / Nanotechnology

Nummer: Number
11LE50MO-5106

Modulverantwortlicher: Responsible person
Prof. Dr. M. Zacharias

Einrichtung: Organisational unit
Chair for Nanotechnology

Modultyp: Module Type
Elective Module

Modulverantwortlicher: Responsible person
Modulverantwortlicher: Responsible person

Modulverantwortlicher: Responsible person
Modulverantwortlicher: Responsible person

Modulverantwortlicher: Responsible person

Modulverantwortlicher: Responsible person
Modulverantwortlicher: Responsible person

Modulverantwortlicher: Responsible person

Modulverantwortlicher: Responsible person

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Basic knowledge in solid state physics

Empfohlenes Fachsemester: Recommended term of study
2 oder 3

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Each term

Arbeitsaufwand: Workload
90 hours
(28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

The aim of the module is to give an introduction into modern methods for the growth of nanomaterials as well as to learn the principles of high resolution investigation (SEM, TEM, HRTEM, STM, AFM, and SNOM). Methods of nanodeposition such as atomic layer deposition (ALD), methods of low dimensional growth (such as molecular beam epitaxy) and methods of self organization are summarized and presented based on selected examples.
The today status of nanolithography (porous nano templates, nanosphere lithography, and interference lithography) will be discussed in details. The module gives instructions in basic knowledge of nanoscaled growth as well as in understanding the basics in high resolution structural investigation techniques of nanostructures. In addition, the module will develop a basic theoretical understanding for size effects on the nanoscale and will give a deeper understanding of state of the art nanotechnology as well as future developments.

### Inhalte Vorlesung / Content of the lecture

After a short introduction in nanotechnology the lecture will start with discussing different size effects from point of physics as well as applications. After that the methods and equipments used for defined growth of nanostructures and nanolayers will be presented and advantages and disadvantages of the various methods will be demonstrated on selected examples. Quantum structures based on III-V semiconductors representing the modern status of optoelectronic LED and laser devices, silicon nanocrystal based structures, nanotubes (carbon, spinel), and photonics crystals are used as example for applications of nanostructures in optics and electronics. In relation to our own research methods for spatially arranged nanowire growth are discussed. The lectures will also include knowledge on the development of nanodevices (memories, nanosensors, nanolaser) and the basic structural, optical and electronic investigation.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Netzfreie Methoden in technischen Anwendungen / Particle Methods in Engineering

Nummer: Number  
11LE50MO-5122

Modulverantwortlicher: Responsible person  
Prof. Dr. S. Hiermaier

Einrichtung: Organisational unit  
Chair for Sustainable Systems Engineering

Modultyp: Module Type  
Elective Module

Moduldauer: Module duration  
1 term

Zugehörige Lehrveranstaltungen: Connected events  
Lecture and Exercises

Sprache: Language  
English

Empfohlenes Fachsemester:: Recommended term of study  
3  
ECTS-Punkte: ECTS-points  
6

SWS: Semester week hours  
2 Lecture + 1 Exercises  
Angebotsfrequenz: Regular cycle  
Only in the summer term

Arbeitsaufwand: Workload  
180 hours  
(42 Hours Full-time attendance course of study + 138 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

Meshfree methods are recognized as alternative spatial discretization technique. Specific advantages in describing large deformation type processes like automotive crash, bird strike or meteoroid impact are seen as well as the numerical problems in terms of stability and convergence. Students learn the differences between meshfree methods and standard methodologies like finite element, finite differences or finite volume approaches. Application show the specific potential of meshfree methods as well as their limitations.

Inhalte Vorlesung / Content of the lecture
<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the
fundamentals of light-matter interaction as well as effects that are widely used in many applications. Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.

Inhalte Vorlesung / Content of the lecture

14. Classification of optical materials
15. Fabrication
16. Interaction of light and matter
17. Pulse propagation in dispersive materials
18. Birefringence
19. Faraday effect
20. Nonlinear-optical effects
21. Pockels effect
22. Kerr effect
23. Photorefractivity
24. Frequency conversion
25. Optical parametric oscillators
26. Optical whispering galleries

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“
- A. Yariv, ”Photonics: Optical Electronics in Modern Communications“
### Modul / Module

**Polymere in der Membrantechnik / Polymers in Membrane Technology**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5114</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

#### Empfohlenes Fachsemester:: Recommended term of study

| 2 | ECTS-Punkte: ECTS-points | 3 |

#### SWS: Semester week hours

| 2 Lecture | Angebotsfrequenz: Regular cycle | Only in the summer term |

#### Arbeitsaufwand: Workload

| 90 hours (28 hours Full-time attendance course of study + 62 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

- Gain awareness for separation needs and sustainability impact
- Understand principles of separation
- Understand membrane fabrication and (polymeric) membrane material properties
- Apply polymeric surface modifications to mitigate material limitations and enable new processes
Inhalte Vorlesung / Content of the lecture

The lecture will focus on polymeric materials for membrane separation technologies. The scope of applications that will be discussed ranges from water to oil & gas, biotech, dialysis to food with a focus on water filtration technologies. Creating awareness for major societal challenges like clean water supply, health care / quality of life and minimization of energy consumption and for contributions that membrane technologies can offer to sustainable solutions for these challenges will be key learning objectives. Focus will be on materials and membrane fabrication / post-modification processes as well as on the underlying principles of separation. Process engineering will be of minor importance. The lecture will concentrate on cognitive levels ‘understanding’ and ‘application’ (Bloom’s taxonomy), case studies will touch upon higher levels.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Various materials are available on the website Homepage: http://www.imtek.de/cpi
### Modul / Module

**Polymerchemie für Ingenieure / Polymer Chemistry for Engineers**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5399</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Chemistry and Physics of Interface</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Organic Chemistry for Microsystems Engineering</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>B.Sc. lectures in Chemistry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Irregular</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
<td>(56 hours Full-time attendance course of study + 34 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective module for students of following study programmes:

- Master of Science im Fach Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science im Fach Mikrosystemtechnik
  - Life sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science im Fach Microsystems Engineering
  - Life sciences: Biomedical Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

This lecture will enable participants to understand how the molecular structure of polymers influences their properties. They will thus be able to choose the right polymer for their applications.
### Inhalte Vorlesung / Content of the laboratory

This lecture includes:

- Surface modifications, techniques and components
- Manufacturing biochips
- State of the art, an overview
- Nucleic acid based biochip analytics
- Protein biochip technologies
- Complex biochip applications

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Quantenmechanik für Ingenieure / Quantum mechanics for engineers

Nummer: Number 11LE50MO-5107

Modulverantwortlicher: Responsible person Prof. Dr. O. Paul

Einrichtung: Organisational unit Chair for Microsystem Materials

Modultyp: Module Type Elective Module

Moduldaeuer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge in Semiconductor Physics or Physical Electronics

Empfohlenes Fachsemester:: Recommended term of study 2

ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 2 lecture + 2 exercises

Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 180 hours (56 hours Full-time attendance course of study + 124 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

The goal is to introduce the students to the main effects of quantum mechanics relevant in technical micro and nano devices. Current semiconductor components in which quantum
mechanics plays a role are discussed in depth. The course successively develops the basic mathematical methods required to solve one, two and three-dimensional problems. The understanding is deepened by practical exercises.

Inhalte Vorlesung / Content of the lecture

- Introduction: Historical overview, unsolved problems at the beginning of the 20th century, probability amplitudes, uncertainty relation
- Wave mechanics: Schrödinger equation, separation of variables, free particle, reflection at wall, potential step, transfer matrix method, wave packets,
- Tunneling: Principle, semiconductor tunneling devices, potential barriers, WKB approximation, triangular potential wall
- Bound states, resonances, and band structure: Potential well, tunneling between wells, infinite series of potential wells
- Single electron transistors: Double-junction SETs, Coulomb barrier, Coulomb staircase, gate-biased SETs, single-electron turnstile, single-electron pumps

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Lecture notes.
Modul / Module

Siliziumbasierte Neurosonden / Silicon-based Neural Technology

Nummer: Number
11LE50MO-5116

Modulverantwortlicher: Responsible person
Prof. Dr. O. Paul

Einrichtung: Organisational unit
Chair for Microsystem Materials

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlenes Fachsemester: Recommended term of study
3

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

Students are offered a detailed overview of silicon-based probe arrays applied in fundamental neuroscientific research. They learn how these probes can be combined with specific materials to cover a broad range of needed functionalities. The students get familiarized with the basic requirements in view of system layout and function. They learn the fabrication technologies used to realize probes and systems.

Inhalte Vorlesung / Content of the lecture

- Introduction – Basic requirements of the field of neuroscience
- Electrical probes
- Fluidic probes
- Optical probes
- Chemotrodes
- IC technologies for signal amplification and data processing
- Assembly technologies

In order to be admitted to the final module exam regular attendance in the lecture is required. The presence in the lecture is monitored by an attendance list.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Recent conference and journal contributions
Modulhandbuch M.Sc. Mikrosystemtechnik – Techniken zur Oberflächenmodifizierung / Surface Coating Techniques

Modul / Module

Techniken zur Oberflächenmodifizierung / Surface Coating Techniques

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5109</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study

| 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 hours Full-time attendance course of study + 58 hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

This module describes all aspects for surface modification as often used in microsystems engineering. It tackles questions on the chemistry of the various approaches and discussion the advantages and shortcomings of a number of methods. Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings.
Inhalte Vorlesung / Content of the lecture

Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings and techniques will be described that yield surface attached polymer monolayers and multilayer assemblies. Examples from current research topics will be discussed.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Modul / Module

**Teststrukturen und Methoden für ICs and MEMS / Test Structures and Methods for ICs and MEMS**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystem Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>MEMS and IC Processing, Semiconductor Physics</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
</table>

### SWS: Semester week hours

<table>
<thead>
<tr>
<th>2 lecture + 1 exercises</th>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only in the winter term</td>
<td></td>
</tr>
</tbody>
</table>

### Arbeitsaufwand: Workload

| 180 hours (48 Hours Full-time attendance course of study + 132 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The aim of this module is to introduce the most relevant material properties, i.e., electrical, mechanical, thermal and magnetic, for materials used in MEMS to realize sensors and actuators and the respective characterization methods to extract these material properties. This theoretical part of the lecture is accomplished with a lab class where the students have to extract material properties by themselves and a seminar section, where actual publications in the field of test structures are presented by the students in 20-minute-talks.
## Inhalte Vorlesung / Content of the lecture

1. **Introduction**
   - 1.1 Purpose of lecture
   - 1.2 Examples and background
   - 1.3 Organization
   - 1.4 References

2. **Geometry**
   - 2.1 Film thickness
   - 2.2 Lateral dimensions

3. **Mechanical properties**
   - 3.1 Fundamentals
     - Stress-strain relations; Brittle vs. ductile materials; Fatigue and fracture mechanics; Parameters: Young’s modulus, shear modulus, residual stresses, coefficient of thermal expansion, fracture and yield strengths, Weibull parameters, strain hardening coefficient, creep and relaxation constants; Mechanics of beams and membranes
   - 3.2 Test methods
     - Wafer curvature method; Nanoindentation; Beam bending; Resonance frequency measurements; Surface micromachined structures; Microtensile test; Membrane deflection

4. **Magnetic properties**
   - 4.1 Fundamentals
     - Magnetostatics, Lorentz force and Biot-Savart law; Magnetic materials; Inductances and inductors; Magnetic forces and torques (Hall effect, Ampere’s law, stored magnetic energy and mutual inductance); Time-varying fields. Electromagnetic induction
   - 4.2 Test methods

5. **Electrical properties**
   - 5.1 Fundamentals
     - Electrical resistivity and contact resistance; Carrier and doping density; Carrier mobility; Carrier lifetime; Electrode impedance
   - 5.2 Test methods
     - van der Pauw method; Spreading resistance measurement; Contact resistance; CV-method; Hall effect, magneto resistance; Photoconductance decay; Electrode impedance teststructures

6. **Thermal properties**
   - 6.1 Fundamentals
     - Thermal conductivity; Heat capacity; Thermoelectric effect
   - 6.2 Test methods
     - Macrosopic systems; MEMS based testsystems

7. **Coupled domains properties**
   - 7.1 Magnetic-, mechanical-, thermal-, chemical- and radiative-magnetic
   - 7.2 Electrical-, mechanical-, thermal-, chemical- and radiative-mechanical
   - 7.3 Electrical-, magnetic-, thermal-, chemical- and radiative-thermal
   - 7.4 Electrical-, magnetic-, mechanical-, thermal- and radiative-chemical
   - 7.5 Electrical-, magnetic-, mechanical-, thermal- and chemical-electrical

8. **Laboratory courses**
   - 8.1 Electrical properties
   - 8.2 Mechanical properties
   - 8.3 Thermal properties

9. **Seminar presentations**
Inhalte Übung / Content of the exercises

The successful completion of the exercise part of the course necessitates the preparation and delivery of a 20-minute seminar talk. Success is achieved when the talk is rated with a grade of 4 or better. The preparation of the talks by the students allows them to deal in depth with novel scientific findings in the area of the lecture. These findings have to be cast into a form that is both concise and understandable for the other participants. The person responsible for the lecture will assign topics in line with the content of the lecture.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

**Modul / Module**

**Verbindungshalbleiter / Compound semiconductor devices**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5111</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ambacher</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Compound Semiconductor Microsystems</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| ECTS-Punkte: ECTS-points | 3 |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

### Inhalte Vorlesung / Content of the lecture

Spannende und neue physikalische Eigenschaften ergeben sich aus den immer kleiner werdenden Abmessungen von mechanischen, elektrischen und optischen Bauelementen aus Verbindungshalbleitern (GaN, GaAs, InP). In einer Einführung in die Welt der Verbindungshalbleiter-Mikrosysteme wird die Physik sowie die Technologie zur Herstellung von kleinsten Leuchtdioden und Lasern, mikromechanischen Filtern und Resonatoren sowie kleinsten Sensoren zur Analyse biologischer Prozesse vorgestellt. Neuartige Bauelemente aus Verbindungshalbleitern werden in ihrer Funktionsweise erläutert und ihre Relevanz für unser tägliches Leben dargestellt.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Rainer Waser (Ed.) Nanoelectronics and Information Technology, Wiley-VCH Verlag GmbH & Co, 2003
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld

Modulnummer: 11LE50MO-5101

Modulverantwortlicher: Prof. Dr. J. Rühe
Einrichtung: Chair for Chemistry and Physics of Interfaces

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture
Sprache: English

Empfohlenes Fachsemester: 3
ECTS-Punkte: 3

SWS: 2 Lecture
Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 90 hours
(32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

This module describes the issues encountered at the transition from the world of Microsystems to the nanoworld. It aims at an understanding of the principle concepts for both worlds and describes current trends and problems in the field. It is also attempted to give an outlook for future research within the boundaries of physics.
### Inhalte Vorlesung / Content of the lecture

<table>
<thead>
<tr>
<th>1. INTRODUCTION</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2. FOUNDATIONS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3. PROBLEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Micro to Nano: what’s different. Physical and societal limits of nano engineering.</td>
</tr>
</tbody>
</table>

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Werkstoffdynamik / Dynamics of Materials**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5118</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S Hiermaier</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sustainable Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours 2 Lecture + 2 Lecture</td>
<td></td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application Field Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

Aim of the module is the knowledge of experimental and numerical basics on the mechanical behavior of materials under dynamic loading conditions. It enables the students in deriving strain-rate dependent stress-strain relations and in implementing the resulting constitutive models into numerical codes. General aim is the basic ability for experimental characterization and numerical modeling of dynamic material behavior.
### Inhalte Vorlesung / Content of the lecture

**Material Characterization:**
- Static versus dynamic material testing
- Strain-rate as measure for dynamics in materials
- Wave propagation as means of material testing
- Strain-rate-dependent elasticity, plasticity and failure
- Constitutive strain-rate dependent models
- Mathematical models for code implementation
- Shock-waves in solids
- Equations of State as component of the stress tensor
- Nonlinear Equations of State

**Numerics of Dynamic Deformation Processes:**
- Spatial and Time Discretization of dynamic deformation on solids
- Finite differences for space and time
- Finite Element Basics
- Implicit and explicit time integration
- Mesh-free Discretization

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Literature

- In addition, lecture notes will be provided
Concentration-Area Microsystems Engineering – MEMS processing

The Concentrations direction “MEMS processing” is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

Modul / Module

Oberflächenanalyse / Surface Analysis

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5606-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study | 2 | ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture | Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

XPS, TEM, FTIR, UPS, SEM, AFM, SPR, GIR, ATR, STM?? Got it?
The performance of microsystems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in microsystems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of microsystems engineering.

Inhalte Vorlesung / Content of the lecture

The techniques presented are grouped into three general topics which are imaging of surfaces (electron microscopy, scanning probe techniques), chemical analysis (XPS, SIMS, FTIR) of the composition of surfaces and methods for the determination of thicknesses (Ellipsometry, XRR, Surface Plasmon Spectroscopy) of layers. General topics from the surface sciences such as adhesion, wetting, and adsorption processes are also presented together with the techniques.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Various materials are available on the website.
**BioMEMS**

<table>
<thead>
<tr>
<th>Modul / Module</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number:</td>
<td>11LE50MO-5403</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in &quot;Sensors&quot; or &quot;Sensors and actuators&quot;</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: Recommended term of study | 2 | ECTS-Punkte: ECTS-points | 3 |
|------------------------------------------------------|--|--|-
| SWS: Semester week hours | 1 Lecture | Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours (14 Hours Full-time attendance course of study + 76 Hours Self-study) |-

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - MEMS Processing
  - Personal Profile

**Lernziele / Learning target**

The students will obtain knowledge in different topics of microsystems comprising biological components as well as microsystems for biological applications. They will obtain a profound understanding of the underlying biological and microsystems concepts by several selected examples. The final learning objective is the understanding of connections between biology, biochemistry, microfluidics, medicine and micro engineering as well as the application of this understanding to future topics in this field.
## Inhalte Vorlesung / Content of the lecture

- Introduction
- Biochemistry and cells
- Cell culture monitoring
- Tissue engineering and cell handling
- Cell mechanics
- Single cell analysis
- Sensors based on microorganism
- Immunoassays and immunosensors
- DNA and RNA analytics on chip
- Implantable devices, in vivo sensors
- “Wellness MEMS”

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
CMOS-Integrated Microsystems / CMOS-Integrated Microsystems

**Number:** 11LE50MO-5716

**Modulverantwortlicher:** Prof. Dr. O. Paul

**Einrichtung:** Chair for Microsystems Materials

**Modultyp:** Elective Module

**Moduldauer:** 1 term

**Zugehörige Lehrveranstaltungen:**

Lecture and exercises

**Sprache:** English

**Empfohlenes Fachsemester:** 2

**ECTS-Punkte:** 6

**SWS:** 2 lecture + 2 exercises

**Angebotsfrequenz:** Only in the summer term

**Arbeitsaufwand:** 180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - MEMS Processing
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - MEMS Processing
  - Personal Profile

**Lernziele / Learning target**

The most successful microsystems to date have been based on silicon. Companies such as Bosch, Analog Devices, Texas Instruments, Sensirion, and other small and medium enterprises have built their success on this wise technological choice. The lecture deals with microsystems compatible with silicon foundry services and commercial silicon technologies, in particular CMOS technologies. It will offer a healthy mix of technology, physical sensor principles and operating techniques, and will be enriched with examples that made it into the market and others that have remained scientific visions. In tune with the progress of the
lecture material, home-work will be assigned, with the presentation and discussion of solutions by students during the course hours.

**Inhalte Vorlesung / Content of the lecture**

- Introduction
- Basic technologies
- Magnetic sensors
- Radiation sensors
- Stress sensors
- Inertial sensors
- Thermal sensors
- Chemical sensors
- Material parameters
- System integration

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5602</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td>(32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

## Lernziele / Learning target

The aim of the module is to provide the in-depth theoretical foundations and the specific technical knowledge of the micro-electro-chemical processes as well as the methodology to benchmark the process with alternative technical methods.

## Inhalte Vorlesung / Content of the lecture

- Electrochemical fundamentals (Galvanic and Corrosion Cell)
- Batteries and fuel cells
- Thermodynamics
- Nernst, Butler-Vollmer, Faraday, Porbaix
- Double layer models (Helmholtz, Gouy-Chapman Stern-Doppelschicht Grahame Bockris-Müller-Devananthan Schmickler und Henderson Trasatti-Buzzanca Conway Marcus-Theory)
- Electroplating, electrolyte compositions (Ni, Au, Cu, alloys), Material properties (stress, hardness, surface roughness), MST applications
- Electrochemical machining (ECM), electrolyte compositions, Technology and variants, MST applications
- Comparison and benchmark to Spark Erosion, Technology, process characteristics, MST applications, validation and results

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accompanying the lecture, a script is provided and updated regularly.</td>
</tr>
</tbody>
</table>
Fortgeschrittene Aufbau- und Verbindungstechnik / Advanced Assembly and Packaging Technology

Nummer: 11LE50MO-5601

Modulverantwortlicher: Prof. Dr. J. Wilde

Einrichtung: Chair for Assembly and Packaging Technology

Modultyp: Elective Module

Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture

Sprache: English

Empfohlene Voraussetzungen: Good knowledge of assembly and packaging technologies from the compulsory lecture

Empfohlenes Fachsemester: 2 ECTS-Punkte: 3

ECTS-Punkte:

SWS: 2 Lecture Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o MEMS Processing
  o Personal Profile
- Master of Science in Microsystems Engineering
  o MEMS Processing
  o Personal Profile

Lernziele / Learning target

It is the aim, that after this module the students will be able to understand advanced problems in the field of assembly and packaging. Furthermore it is intended that the students will have capabilities to resolve A&P-related research tasks for micro-systems. The employed methods will start with system concepts and comprise thermal, electrical and mechanical modelling and optimisation. As a basis the student will know the fundamental
elements of A&P as well as the specific technologies for interconnection, assembly and protection. Also, the students will become familiar with the materials, their processing and properties. In this way they have the abilities for own research on micro-systems.

### Inhalte Vorlesung / Content of the lecture

The contents of teaching are mainly based on actual research projects in the chair Aufbau- und Verbindungstechnik.

Organization of the lecture:
- Introduction
- Thermal management using novel materials
- Packaging of MEMS pressure sensors
- Fatigue analysis of soldered joints
- Adhesive bonding of power electronics
- Computation of packaging stress in Hall sensors
- Concepts for sensors for mechanical properties
- High-temperature packaging
- Materials modelling in A&P
- Reliability modelling in A&P

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

**Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5112</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystems Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in Microsystems technology and semiconductor physics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

This module provides a more detailed description of silicon technologies exceeding the modules in Microsystemtechnology I and II. The basics in silicon technologies will be accomplished by the most recent results found in literature. Whenever possible, we will organize a visit of the Micronas GmbH in Freiburg and their CMOS Fab.
### Content of the lecture

| Substrate materials, oxidation, diffusion, implantation, polysilicon and epitaxy, silicides, metallisation, dielectric layers, SiGe, strained silicon, low- and high-k-dielectrics, photo lithography (immersion lithography, phase shift mask, EUV, chemical-mechanical polishing, process integration, CMOS-compatible micro mechanics |

### Examination result

| written or oral examination |

### Grading

| The module grade is calculated from the result of the final examination. |

### Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literature

- Chang/Sze: ULSI Technology, Wiley
- Semiconductor International: monatliche Technologie-Zeitschrift
**Modul / Module**

**Lithographie für Microsystems Engineers/ Litography for Microsystems Engineers**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5608</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair for Process Technology</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Knowledge of the modules</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• MST Technologies and Processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cleanroom Laboratory</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester::**

<table>
<thead>
<tr>
<th>Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>ECTS-points</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SWS:</td>
<td>Semester week hours</td>
</tr>
<tr>
<td>2 Lecture</td>
<td></td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Regular cycle</td>
</tr>
<tr>
<td>Only in the summer term</td>
<td></td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>Workload</td>
</tr>
<tr>
<td>90 hours</td>
<td></td>
</tr>
<tr>
<td>(28 hours Full-time attendance course of study + 62 hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

**Lernziele / Learning target**

At the end of the block seminar the students should have learned the basic knowledge to perform a simple troubleshooting for photoresist processing in a cleanroom environment and should be able to choose the appropriate technique for the realization of micro- or nanostructures.

**Inhalte Vorlesung / Content of the lecture**

The purpose of this block course is to deepen the existing knowledge of lithography for micro structures (gained by the lecture “MST- Technologies and Processes”) and to learn the basics of alternative state-of-the-art lithography techniques such as nanoimprinting (UV-
NIL, HEL, etc.), interference lithography, contact printing. The students will be introduced to a more profound knowledge of the working principles of modern photo resists used in Microsystems Technology. The necessary equipment and tools for lithography are also covered (mask-aligner, photo mask, microscope, etc.).

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Bepotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Marc Madou "Fundamentals of Microfabrication"
- Hand-Outs to the single subjects will be provided at the block seminar.
**Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components**

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5604</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Materials Processing</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:** Recommended term of study | 3 |
| **ECTS-Punkte:** ECTS-points | 3 |

**SWS:** Semester week hours | 2 Lecture |
| **Angebotsfrequenz:** Regular cycle | Only in the winter term |

| **Arbeitsaufwand:** Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

Besides silicon and the established MEMS/MOEMS technology polymer materials and the related microreplication technologies are becoming more and more important for the realization and commercial success of new microcomponents and microsystems. New nanostructuring methods like 2-photon-stereolithography and others are at the threshold of leaving the laboratory status and entering market. The course will cover the large variety of polymer materials, their fundamental chemical and physical properties and the derived
microstructuring and replication possibilities. Direct and indirect micro- and nanostructuring methods like deep X-ray lithography, stereolithography, laser machining, nanoimprinting and others as well as the large family of replication methods like hot embossing and injection molding will be described in detail. Master and tooling fabrication methods like electroplating, electro discharge machining as well as mechanical and laser micromachining will be presented and discussed intensely. A large number of application examples and case studies dealing with the accessible geometries, feasibility, and process characteristics will be used for the presentation of the polymer microfabrication importance.

### Inhalte Vorlesung / Content of the lecture

**Contents:**
- Polymers: Fundamental chemical and physical properties
- Fabrication of molding tools: Fabrication principles and characteristics
- Rapid Prototyping in microsystem technology
- Polymer replication techniques: Reaction Molding, UV-Embossing, Hot Embossing and Injection Molding: Principles, equipment, applications and case studies
- From micro to nano: Nanoimprinting, soft lithography, nanostereolithography and other new developments

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

### Modul / Module

**Mold Flow Simulation für Replikationsprozesse / Mold Flow Simulation for Replication Processes**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5605</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendungbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

The module is focusing on the theoretical concepts and algorithm of process simulation for micro replication. Design Rules for Micro- Nano replication will be formulated. Gate and runner Balancing, cavity design and the influence on crystallisation, shrinkage and warpage will be studied. Experimental results obtained under different processing conditions will be simulated by state of the art software tools.

### Inhalte Vorlesung / Content of the lecture

- Design of Material for Products
- Thermoset and rubber
- Amorphous polymer
- Semi crystalline polymer
- Process and Technology
- Mould and process Control
- Injection Moulding-Micro Injection Moulding
- Extrusion
- Thermoforming
- Fundamental Model for replication
- Thermal
- Mechanical
- Viscoelastic
- Rheology
- Filling, Compression, Packing and Cooling
- The downscaling of replication
- Wall Slip
- Turbulent Flow
- Process Instabilities (Air bubbles, vacuoles)
- Shear Thinning and Heat conduction and heat transfer
- Training on Software tools for simulation
- Material Characterisation
- Mould Model-Machine Model
- Meshing

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Accompanying lecture notes are made available and updated regularly.
## Nanotechnology / Nanotechnology

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5106</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Type:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration:</td>
<td>1 term</td>
</tr>
<tr>
<td>Language:</td>
<td>English</td>
</tr>
<tr>
<td>Basic knowledge in solid state physics</td>
<td></td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:
- 2 oder 3 ECTS-Punkte: 3
- 2 Lecture
- Angebotsfrequenz: Regular cycle

### Arbeitsaufwand:
- 90 hours (28 oder 32 Hours Full-time attendance course of study + 58 oder 62 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module
- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - Master of Science in Embedded Systems Engineering
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Materials
    - MEMS Processing
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Materials
    - MEMS Processing
    - Personal Profile

### Lernziele / Learning target
The aim of the module is to give an introduction into modern methods for the growth of nanomaterials as well as to learn the principles of high resolution investigation (SEM, TEM, HRTEM, STM, AFM, and SNOM). Methods of nanodeposition such as atomic layer deposition (ALD), methods of low dimensional growth (such as molecular beam epitaxy) and methods of self organization are summarized and presented based on selected examples.
The today status of nanolithography (porous nano templates, nanosphere lithography, and interference lithography) will be discussed in details. The module gives instructions in basic knowledge of nanoscaled growth as well as in understanding the basics in high resolution structural investigation techniques of nanostructures. In addition, the module will develop a basic theoretical understanding for size effects on the nanoscale and will give a deeper understanding of state of the art nanotechnology as well as future developments.

### Inhalte Vorlesung / Content of the lecture

After a short introduction in nanotechnology the lecture will start with discussing different size effects from point of physics as well as applications. After that the methods and equipments used for defined growth of nanostructures and nanolayers will be presented and advantages and disadvantages of the various methods will be demonstrated on selected examples. Quantum structures based on III-V semiconductors representing the modern status of optoelectronic LED and laser devices, silicon nanocrystal based structures, nanotubes (carbon, spinel), and photonics crystals are used as example for applications of nanostructures in optics and electronics. In relation to our own research methods for spatially arranged nanowire growth are discussed. The lectures will also include knowledge on the development of nanodevices (memories, nanosensors, nanolaser) and the basic structural, optical and electronic investigation.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Oberflächenanalyse – Laboratory / Surface Analysis Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5311</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

**Lernziele / Learning target**

Microsystems – especially those for microfluidics – are dominated by their surfaces due to their surface to volume ratio. This strong influence of surfaces is also important for devices e.g. sensors that are in contact with biological fluids. Surface analytical methods are, hence, often at the center of research questions in microsystems engineering. The Surface Analysis Laboratory introduces selected methods in this field and discusses strengths and limitations of each technique. It concentrates on surface analytical questions which are relevant for the life sciences.
### Inhalte Praktikum / Content of the laboratory

<table>
<thead>
<tr>
<th>Topic 1:</th>
<th>Determination of the layer thickness and roughness of biocompatible coatings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1:</strong></td>
<td>Using ellipsometry and x-ray reflectometry to determine the thickness of hydrogel coatings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 2:</th>
<th>Wetting of surfaces – Surface free energies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 2:</strong></td>
<td>Measurement of the contact angles of test liquids in various surfaces; Determination of the surface free energy using the Zisman method</td>
</tr>
<tr>
<td><strong>Experiment 3:</strong></td>
<td>Generation and characterization of microarrays on various surfaces</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 3:</th>
<th>Proteins / peptides on surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 4:</strong></td>
<td>Measurement of the adsorption of blood proteins on surfaces using Surface Plasmon Resonance</td>
</tr>
<tr>
<td><strong>Experiment 5:</strong></td>
<td>Characterization of the structure of protein layers using Fourier Transform Infrared Spectroscopy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 4:</th>
<th>DNA at surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 6:</strong></td>
<td>Visualisation of DNA on mica using the Atomic Force Microscope</td>
</tr>
</tbody>
</table>

### Zu erbringende Prüfungsleistung / Examination result

Before each experiment there will be an oral examination and for each experiment the student has to submit a written laboratory report.

### Benotung / Grading

The module grade will be determined from the average of the grades of the oral examinations and the laboratory reports.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture notes.
Modulhandbuch M.Sc. Mikrosystemtechnik – Optimierung von Fertigungsverfahren / Advanced engineering

Modul / Module

Optimierung von Fertigungsverfahren / Advanced engineering

Nummer: Number
11LE50MO-5607

Modulverantwortlicher: Responsible person
N.N.

Einrichtung: Organisational unit
Chair for Process Technology

Modultyp: Module Type
Elective Module

Moduldaener Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
- Statistical Basics
- Fundamentals of Manufacturing Technology
- Processes of microsystem technology (clean room fabrication and conventional environment)

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Mikrosystemtechnik
  o MEMS Processing
  o Personal Profile
- Master of Science in Microsystems Engineering
  o MEMS Processing
  o Personal Profile

Lernziele / Learning target

- Learn how to make complex processes controllable with minimum experimental effort a maximum on process significance.
- How to optimize technical results towards no rejects, towards zero failure production.
- Extension of the mathematical methods to organizational structures and management.
### Inhalte Vorlesung / Content of the lecture

- Design of Experiments
- Tolerancing and tolerance stacking
- Failure Mode and Effects Analysis
- Continuous Improvement Process
- General business and management methods for this purpose

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- George E. P. Box, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building (Wiley Series in Probability and Statistics)
- Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes using Failure Mode and Effects Analysis Hardcover – May 15, 2012 by Carl Carlson
Modulhandbuch M.Sc. Mikrosystemtechnik – Siliziumbasierte Neurosonden / Silicon-based Neural Technology

**Modul / Module**

**Siliziumbasierte Neurosonden / Silicon-based Neural Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystem Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester: Recommended term of study**
- 3

**ECTS-Punkte: ECTS-points**
- 3

**SWS: Semester week hours**
- 2 Lecture

**Angebotsfrequenz: Regular cycle**
- Only in the winter term

**Arbeitsaufwand: Workload**
- 90 hours
  - (32 hours Full-time attendance course of study + 58 hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

**Lernziele / Learning target**

Students are offered a detailed overview of silicon-based probe arrays applied in fundamental neuroscientific research. They learn how these probes can be combined with specific materials to cover a broad range of needed functionalities. The students get familiarized with the basic requirements in view of system layout and function. They learn the fabrication technologies used to realize probes and systems.

**Inhalte Vorlesung / Content of the lecture**

- Introduction – Basic requirements of the field of neuroscience
- Electrical probes
- Fluidic probes
- Optical probes
- Chemotrodes
- IC technologies for signal amplification and data processing
- Assembly technologies

In order to be admitted to the final module exam regular attendance in the lecture is required. The presence in the lecture is monitored by an attendance list.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Recent conference and journal contributions.
Modulhandbuch M.Sc. Mikrosystemtechnik – Teststrukturen und Methoden für ICs and MEMS / Test Structures and Methods for ICs and MEMS

Modul / Module

Teststrukturen und Methoden für ICs and MEMS / Test Structures and Methods for ICs and MEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystem Materialien</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>MEMS and IC Processing, Semiconductor Physics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (48 Hours Full-time attendance course of study + 132 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The aim of this module is to introduce the most relevant material properties, i.e., electrical, mechanical, thermal and magnetic, for materials used in MEMS to realize sensors and actuators and the respective characterization methods to extract these material properties. This theoretical part of the lecture is accomplished with a lab class where the students have to extract material properties by themselves and a seminar section, where actual publications in the field of test structures are presented by the students in 20-minute-talks.
Inhalte Vorlesung / Content of the lecture

10. Introduction
   o 1.1 Purpose of lecture
   o 1.2 Examples and background
   o 1.3 Organization
   o 1.4 References

11. Geometry
   o 2.1 Film thickness
   o 2.2 Lateral dimensions

12. Mechanical properties
   o 3.1 Fundamentals
     Stress-strain relations; Brittle vs. ductile materials; Fatigue and fracture mechanics;
     Parameters: Young’s modulus, shear modulus, residual stresses, coefficient of thermal expansion,
     fracture and yield strengths, Weibull parameters, strain hardening coefficient, creep and relaxation constants;
     Mechanics of beams and membranes
   o 3.2 Test methods
     Wafer curvature method; Nanoindentation; Beam bending; Resonance frequency measurements;
     Surface micromachined structures; Microtensile test; Membrane deflection

13. Magnetic properties
   o 4.1 Fundamentals
     Magnetostatics, Lorentz force and Biot-Savart law; Magnetic materials;
     Inductances and inductors; Magnetic forces and torques (Hall effect, Ampere’s law, stored magnetic
     energy and mutual inductance); Time-varying fields. Electromagnetic induction
   o 4.2 Test methods

14. Electrical properties
   o 5.1 Fundamentals
     Electrical resistivity and contact resistance; Carrier and doping density; Carrier mobility;
     Carrier lifetime; Electrode impedance
   o 5.2 Test methods
     van der Pauw method; Spreading resistance measurement; Contact resistance; CV-method;
     Hall effect, magneto resistance; Photoconductance decay; Electrode impedance teststructures

15. Thermal properties
   o 6.1 Fundamentals
     Thermal conductivity; Heat capacity; Thermoelectric effect
   o 6.2 Test methods
     Macroscopic systems; MEMS based testsystems

16. Coupled domains properties
   o 7.1 Magnetic-, mechanical-, thermal-, chemical- and radiative-magnetic
   o 7.2 Electrical-, mechanical-, thermal-, chemical- and radiative-mechanical
   o 7.3 Electrical-, magnetic-, thermal-, chemical- and radiative-thermal
   o 7.4 Electrical-, magnetic-, mechanical-, thermal- and radiative-chemical
   o 7.5 Electrical-, magnetic-, mechanical-, thermal- and chemical-electrical

17. Laboratory courses
   o 8.1 Electrical properties
   o 8.2 Mechanical properties
   o 8.3 Thermal properties

18. Seminar presentations
### Inhalte Übung / Content of the exercises

The successful completion of the exercise part of the course necessitates the preparation and delivery of a 20-minute seminar talk. Success is achieved when the talk is rated with a grade of 4 or better.

The preparation of the talks by the students allows them to deal in depth with novel scientific findings in the area of the lecture. These findings have to be cast into a form that is both concise and understandable for the other participants. The person responsible for the lecture will assign topics in line with the content of the lecture.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Concentration-Area Microsystems Engineering – Photonics

The Concentrations direction "Photonics" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5231</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics, mathematics and micro-optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
## Lernziele / Learning target

In this module we consider topics in micro-optics in greater depth than is possible in the introductory course Micro-optics, which is a prerequisite. At the completion of the course, the successful student should possess:

- the ability to understand and analyze multi-lens and thick lens systems
- an understanding of the basics of numerical modeling as well as characterization techniques for optics
- the ability to understand the structure and function of some important optical instruments
- an awareness of the most important devices and effects in MOEMS, nano-optics and tunable optics
- the ability to understand and apply these concepts in microsystems applications

## Inhalte Vorlesung / Content of the lecture

A variety of optical topics with relevance to microsystems engineering is considered. Whereas advanced techniques in geometrical optics analysis, optical modeling instruments, and interferometry apply to macro as well as micro-optical systems, the later topics, including MOEMS and optofluidics, are of prime importance in optical microsystems and their applications.

Table of contents:
- Advanced geometric optics
- Optics modeling
- Optical instruments
- Interferometry
- Optics characterization
- Optical multilayers
- MOEMS
- Tunable optics
- Optofluidics

## Zu erbringende Prüfungsleistung / Examination result

oral presentation

## Benotung / Grading

The module grade will be determined from the grade of the presentation.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
ECTS-points in the calculation of the overall grade.

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- L. Novotny & B. Hecht: Principles of Nano-optics
- W. Smith: Modern Optical Engineering
- S. Gaponenko: Introduction to Nanophotonics
Modulhandbuch M.Sc. Mikrosystemtechnik – Optik-Laboratory
Grundlagen / Basic Optics Laboratory

Optik-Laboratory Grundlagen / Basic Optics Laboratory

Nummer: Number
11LE50MO-5213

Modulverantwortlicher: Responsible person
Prof. Dr. H. Zappe

Einrichtung: Organisational unit
Gisela and Erwin Sick
Chair of Micro-optics

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Laboratory

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Basic knowledge in physics and mathematics; Knowledge in Micro-optics

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Laboratory

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

Lernziele / Learning target

The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.

At the completion of the course, the successful student should possess:
- the ability to analyze measurement data and estimate errors;
- the ability to apply error propagation methods;
- the ability to assemble and align optical systems;
- a basic understanding of optical design methods;
- the ability to apply optical measurement techniques;
- the ability to apply analytical and graphical techniques for analyzing optical images.

**Inhalte Praktikum / Content of the laboratory**

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:
- Statistics and data analysis
- Error propagation
- Focal length of lenses
- Focal length of lens systems
- Construction of a microscope
- Diffraction from gratings
- Newton’s rings
- Fiber optics
- Construction of an interferometer
- Polarization

**Zu erbringende Prüfungsleistung / Examination result**

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

**Bewertung / Grading**

The final module grade is determined from an average of the grades of the individual reports.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In German:</strong></td>
</tr>
<tr>
<td>- E. Hecht: Optik</td>
</tr>
<tr>
<td>- Walcher: Laboratory der Physik</td>
</tr>
<tr>
<td>- Westphal: Physikalisches Laboratory</td>
</tr>
<tr>
<td>- Geschke: Physikalisches Laboratory</td>
</tr>
<tr>
<td><strong>In English:</strong></td>
</tr>
<tr>
<td>- E. Hecht: Optics</td>
</tr>
<tr>
<td>- B. Saleh &amp; M. Teich: Fundamentals of Photonics</td>
</tr>
<tr>
<td>- S. Sinziger &amp; J. Jahns: Microoptics</td>
</tr>
<tr>
<td>- W. Smith: Modern Optical Engineering</td>
</tr>
<tr>
<td>- P. Hariharan: Basics of interferometry</td>
</tr>
<tr>
<td>- R.R. Shannon: The art and science of optical design</td>
</tr>
<tr>
<td>- D. Malacara: Optical shop testing</td>
</tr>
<tr>
<td>- W.J. Smith: Practical optical system layout</td>
</tr>
</tbody>
</table>
**Modul / Module**

**Optik-Laboratory Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5217</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics and mathematics; Knowledge in Micro-optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2 and 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory + 2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (60 Hours Full-time attendance course of study + 300 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

**Basic Optics Laboratory:**
The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in
making optical measurements. At the completion of the course, the successful student should possess:

- the ability to analyze measurement data and estimate errors
- the ability to apply error propagation methods
- the ability to assemble and align optical systems
- a basic understanding of optical design methods
- the ability to apply optical measurement techniques
- the ability to apply analytical and graphical techniques for analyzing optical images

**Advanced Optics Laboratory:**
The Advanced Optics Laboratory Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the curriculum of the 'Optics Lab Course I' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of modern optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:

- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in modern optical setups

---

**Inhalte Praktikum / Content of the laboratory**

**Basic Optics Laboratory:**
One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:
- Statistics and data analysis
- Error propagation
- Focal length of lenses
- Focal length of lens systems
- Construction of a microscope
- Diffraction from gratings
- Newton's rings
- Fiber optics
- Construction of an interferometer
- Polarization

**Advanced Optics Laboratory:**
This advanced Optics Lab Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the knowledge acquired in the 'Basic Optics Laboratory' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:
- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in optical setups

Table of contents:
- Anamorphic imaging
- Dynamically addressable gratings
- Whispering gallery resonators
- Michelson interferometer and coherence
- Three dimensional light distribution in a 6f system
- Diode pumped solid state laser

Zu erbringende Prüfungsleistung / Examination result
For each experiment, a lab report is required. All experiments must be performed and a lab report written.

Benotung / Grading
The final module grade is determined from an average of the grades of the individual reports in both courses.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
In German:
- E. Hecht: Optik
- Walcher: Laboratory der Physik
- Westphal: Physikalisches Laboratory
- Geschke: Physikalisches Laboratory

In English:
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- S. Sinziger & J. Jahns: Microoptics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- D. Malacara: Optical shop testing
- W.J. Smith: Practical optical system layout

Modul / Module

Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5211</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>PD Dr. A. Gombert</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS:</td>
<td>Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

The objective of this module is learning the fundamentals of technics and physics with respect to the interaction of electro-magnetic waves with predominantly periodically
structured matter. The students will be enabled to predict the qualitative optical properties of micro and nano structured materials with the taught methods. The superior learning target is to master the fundamental capabilities to design diffractive optical elements and optical elements based on subwavelength structures as well as to know their respective technical applications. The students will obtain the engineering know-how for micro and nano optical elements as used in micro systems technology.

## Inhalte Vorlesung / Content of the lecture

Micro and nano structures have optical properties that differ from macroscopic bodies. The interaction between incident light or more generally incident electromagnetic radiation may lead to a modification of the propagation direction, the polarisation, and the spectral signature of absorption, reflection or transmission. In micro systems or similar technologies these phenomena can be used on purpose or need to be considered when manufacturing micro and nano structures. In this lecture we will work on the theoretical fundamentals as well as on selected applications.

Topics:
- Calculating with complex amplitudes
- Energy transfer at boundaries
- Two beam interference
- Huygens` principle
- Fresnel`s zone construction
- Introduction into Fourier optics
- Kirchhoff-Fresnel diffraction integral
- Fresnel diffraction
- Fraunhofer diffraction
- Introduction into diffraction gratings
- Spectroscopic gratings
- Theory and applications of subwavelength gratings
- Photonic crystals
- Resonant structures in metals
- Production technologies for micro structures with optical functions

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- E. Hecht: Optics, Addison-Wesley, 1989
## Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5219</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>4</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (70 Full-time attendance course of study + 110 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

### Lernziele / Learning target

Optical traps and optical micro-manipulation techniques do have the potential to play a key role in future micro- and nanosystems in conjunction with the life sciences. In this lecture the students should learn what is doable with optical forces, where physical limits are and what
is limited by nowadays technology. Besides fascinating fundamental research various applications related to biology or fluctuation based systems are presented. The lecture is manifold and teaches basics in optics, statistical physics and biology/biophysics.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Introduction</td>
</tr>
<tr>
<td>14. Light - Information carrier and actor</td>
</tr>
<tr>
<td>15. About microscopy</td>
</tr>
<tr>
<td>16. Light scattering</td>
</tr>
<tr>
<td>17. Optical forces</td>
</tr>
<tr>
<td>18. Tracking beyond the uncertainty</td>
</tr>
<tr>
<td>19. Brownian motion and calibration techniques</td>
</tr>
<tr>
<td>20. Photonic force microscopy</td>
</tr>
<tr>
<td>21. Applications in cell biophysics</td>
</tr>
<tr>
<td>22. Time- multiplexing and holographics optical traps</td>
</tr>
<tr>
<td>23. Applications in microsystems technology</td>
</tr>
<tr>
<td>24. Applications in nanotechnology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of</td>
</tr>
</tbody>
</table>
2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Optische Materialien / Optical Materials

Nummer: 11LE50MO-5113-2
Modulverantwortlicher: Prof. Dr. K. Buse
Einrichtung: Chair for Optical Systems
Modultyp: Elective Module
Modulauerdauer: 1 term
Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English
Empfohlene Voraussetzungen: Knowledge in Micro-optics

Empfohlenes Fachsemester: 3
ECTS-Punkte: 5
SWS: 2 lecture + 2 exercises
Angebotsfrequenz: Only in the winter term
Arbeitsaufwand: 150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - MEMS Processing
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - MEMS Processing
  - Photonics
  - Personal Profile

Lernziele / Learning target

Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the fundamentals of light-matter interaction as well as effects that are widely used in many
applications. Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.

### Inhalte Vorlesung / Content of the lecture

- Classification of optical materials
- Fabrication
- Interaction of light and matter
- Pulse propagation in dispersive materials
- Birefringence
- Faraday effect
- Nonlinear-optical effects
- Pockels effect
- Kerr effect
- Photorefractivity
- Frequency conversion
- Optical parametric oscillators
- Optical whispering galleries

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“
- A. Yariv, "Photonics: Optical Electronics in Modern Communications"
# Modul / Module

## Optische MEMS / Optical MEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Physical Optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

## Lernziele / Learning target

- Theoretical understanding of fundamental optical phenomena exploited by the MOEMS technology
- Acquisition of the essential skills necessary for the design, microfabrication, modeling, and characterization of MEMS/MOEMS components
- A comprehensive knowledge of MOEMS based commercial systems and a basic
understanding of the particular applications enabled by MOEMS

### Inhalte Vorlesung / Content of the lecture

**Module 1: MOEMS Fundamentals**
- Optics Review
- MEMS Manufacturing Techniques
- Actuators and Position Sensing
- Design and Modeling
- Test and Characterization

**Module 2: MOEMS Devices**
- Micromirrors
- Tunable Gratings
- Active Microlenses
- Tunable Optical Resonators

**Module 3: MOEMS Systems**
- Display and Imaging Systems
- MOEMS in Telecommunication Networks
- Scientific Instrumentation

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

MEMS and MOEMS Related Books
- An Introduction to Microelectromechanical Systems Engineering by N. Maluf
- Micromachined Transducers Sourcebook by G. Kovacs
- Fundamentals of Microfabrication by Marc Madou
- Micro Electro Mechanical System Design by J. Allen
- Analysis and Design Principles of MEMS Devices by Minhang Bao
- The MEMS Handbook by Mohamed Gad-el-Hak
- MOEMS: Micro-Opto-Electro-Mechanical Systems by Manouchehr E. Motamedi
- Foundations of MEMS by Chang Liu
- MEMS & Microsystems by Tai-Ran Hsu

Scientific Journals
- Journal of Microelectromechanical Systems / IEEE
- Journal of Micromechanics and Microengineering / IOP
- Journal of Micro/Nanolithography, MEMS, and MOEMS / SPIE
- Microsystem Technologies / SPRINGER
- Sensors and Actuators A-Physical / ELSEVIER
- Applied Optics / OSA
- Optics Letters / OSA
- Optics Express / OSA
- Applied Physics Letters / AIP
- Journal of Biomedical Optics / SPIE
Modul / Module

Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5710</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. K. Buse</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Optical Systems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study

| 2 |

ECTS-Punkte: ECTS-points

| 3 |

SWS: Semester week hours

| 2 Seminar |

Angebotsfrequenz: Regular cycle

| Only in the summer term |

Arbeitsaufwand: Workload

| 90 hours |

(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

The students gain knowledge about different optical measurement techniques for shape determination of objects or for material characterization. They achieve a deeper understanding of the physical background. Consequently, the participants are able to estimate the fundamental and technological limitations of the methods presented. This enables the students to select an appropriate optical measurement technique for a given task. Furthermore, the participants get trained in preparing and presenting excellent talks.
### Inhalte Seminar / Content of the seminar

During the first meeting the organizers will present a list of topics from which each active participant of the seminar can select one. For each topic literature will be provided. Starting with this material the active participants of the seminar will familiarize themselves with the content. This will be done by discussions as well as by further literature search. Based on the accumulated knowledge, an outline for talks will be made and finally the viewgraphs will be prepared. Then the talk will be presented in the seminar. Typical duration of the talk is 30 minutes. After the talk there will be a discussion about the content. And as a second part of the discussion technical issues of the talk will be analyzed. Finally, a short written summary of the talk will be prepared. Talks can be given in German or English.

This semester, the following topics are available:

- 3d-shape determination
- Optical microresonators for sensing
- Terahertz waves for material characterization
- Photoacoustic spectroscopy
- Laser spectroscopy
- Fluorescence spectroscopy
- and more

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

The advisor will provide literature as a starting package.
**Modul / Module**

| Optische Mikrosensoren / Optical Micro-Sensors |
|---|---|

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5711</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Brandenburg</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Vorlesung</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

Kenntnis der Prinzipien miniaturisierter optischer Sensoren, Vertiefung bei den Gebieten Wegsensorik, Drehratensensoren sowie chemische und biochemische Sensoren.

** Inhalte Vorlesung / Content of the lecture**

- Vorbereitende Inhalte: Grundlagen der Optik (kurze Wiederholung), Lichtwellenleiter.
- Optische Grundlagen für die Sensorik: Interferometrie, Sagnac-Effekt, Spektroskopie, Fluoreszenz.
- Detaillierte Darstellung der Funktion und der technologischen Realisierung von
Wegsensoren, Drehratensensoren, Miniaturspektrometern und fluoreszenzoptischen Sensoren sowie Microarray-Technologien.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. Schröder: Technische Optik, Vogel-Verlag, Würzburg 1980</td>
</tr>
<tr>
<td>T. Tamir (Hrsg.): Guided wave optoelectronics, Springer-Verlag 1988</td>
</tr>
<tr>
<td>W. Schmidt: Optische Spektroskopie, VCH Verlagsgesellschaft Weinheim 1994</td>
</tr>
</tbody>
</table>
Modulhandbuch M.Sc. Mikrosystemtechnik – Photonische Mikroskopie / Photonic Microscopy

**Modul / Module**

**Photonische Mikroskopie / Photonic Microscopy**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5901</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Bio- and Nanophotonics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Lecture + 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td></td>
<td>(80 Hours Full-time attendance course of study + 100 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

The student should learn how to guide light through optical systems, how optical information can be described very advantageously by three-dimensional transfer functions in Fourier space, how phase information can be transformed to amplitude information to generate image contrast. Furthermore one should experience that wave diffraction is not reducing the information and how to circumvent the optical resolution limit. The student should learn to distinguish between coherent and incoherent imaging, learn about modern techniques using self-reconstructing laser beams, two photon excitation, fluorophores depletion through stimulated emission (STED) or multi-wave mixing by coherent anti-Stokes Raman scattering (CARS). The module has an ongoing emphasis on applications, but nevertheless presents a
mixture of fundamental physics, compact mathematical descriptions and many examples and illustrations. The lecture aims to encompass the current state of a scientific field, which will influence the fields of nanotechnology and biology/medicine quite significantly.

### Inhalte Vorlesung / Content of the lecture

1. Microscopy: History, Presence and Future
2. Wave- and Fourier-Optics
3. Three-dimensional optical imaging and information transfer
4. Contrast enhancement by Fourier-filtering
5. Fluorescence – Basics and techniques
6. Point scanning and confocal microscopy
7. Microscopy with self-reconstructing beams
8. Optical tomography
9. Nearfield and Evanescent Field Microscopy
10. Super-resolution using structured illumination
11. Multi-Photon-Microscopy
12. Super resolution imaging by switching single molecules

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Inhalte Übung / Content of the exercises

The tutorials help the student to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
### Modul / Module

**Spektroskopische Methoden / Spectroscopic Methods**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5717</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Thin-film Gas Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Lecture</td>
<td>ECTS-Punkte: ECTS-points</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand:** Workload

90 hours  
(32 Hours Full-time attendance course of study + 58 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**


**Inhalte Vorlesung / Content of the lecture**

Spektroskopische Anwendungen finden sich einer Vielzahl von Industrien, der

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.</td>
</tr>
</tbody>
</table>
Wellenoptik / Wave optics

Modul / Module

Wellenoptik / Wave optics

Nummer: Number
11LE50MO-5221

Modulverantwortlicher: Responsible person
Prof. Dr. A. Rohrbach

Einrichtung: Organisational unit
Chair for Bio- and Nano-Photonics

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlenes Fachsemester:: Recommended term of study
4

ECTS-Punkte: ECTS-points
6

SWS: Semester week hours
3 Lecture + 2 Übung

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
180 hours (70 Hours Full-time attendance course of study + 110 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile
- Master of Science in Physik

Lernziele / Learning target

Goal of this module is to teach the student how light interacts with small structures and how optical systems guide light. The students will start at Maxwell's equations and move on to the description of light as photon or wave, depending on the given problem. Furthermore, the close connection between spatial and temporal coherence, interference and holography is demonstrated. The last chapter teaches concepts of linear and non-linear light scattering, as well as the most important plasmonic effects. In total, the students learn how to shape light in three dimensions and how optical problems that arise in research and development are solved.
Inhalte Vorlesung / Content of the lecture

We do not really know what light is, although the concepts to describe light as waves or as particles usually work well. It is a nontrivial task to explain the colorful intensity distributions we see every day, i.e., the interactions of light with matter. Controlling light on the macroscale and the nanoscale is the key for generating impact in research, development and industry. However, this requires a thorough understanding of wave optics and its powerful theoretical instrument, the description by Fourier transforms.

This English lecture is accompanied by many live experiments and by weekly tutorials, where exercises are discussed that students have to calculate from one week to the next. The new lecture is a fusion of the two former lectures “Moderne Optik I & II” and is now organized in 6 chapters.

1. Introduction
Some motivation, literature and a bit of history

2. From Electromagnetic Theory to Optics
What is light? Which illustrative pictures do the Maxwell equations provide? If matter, dielectric and metallic, consists of coupled, damped springs (harmonic oscillators), how does matter depend on the frequency of light? What do the wave equation and the Helmholtz equation express and how can one handle waves in position space and frequency space.

3. Fourier-Optics
How does a wave transforms position information into directional information? Why can this be well described by Fourier transformations in 1D, 2D and 3D? What has this to do with linear optical system theory including spatial frequency filters and the sampling theorem?

4. Wave-optical Light Propagation and Diffraction
Different methods are introduced of how to describe the propagation of waves in position space and frequency space. We do the direct transfer from propagation to diffraction of light and momentum space. We treat evanescent waves, thin diffracted objects, the propagation of light in inhomogeneous media and the diffraction at gratings. This allows to discuss important active elements such as acousto-optic and spatial light modulators. We end with adaptive optics and phase conjugation.

5. Interference, Coherence and Holography
We learn how a composition of k-vectors define the phases of interfering waves and the resulting stripe patterns. The relative phases of each partial wave in space and time change the interference significantly and define the coherence of light - these concepts will be discussed in detail. We learn how to write and read phase information in holography.

6. Light Scattering and Plasmonics
The interaction of light with matter is based on particle scattering: we discuss the theoretical concepts of light scattering on the background of Fourier theory. We expend these approaches to photon diffusion, nonlinear optics, fluorescence and Raman scattering or scattering at semiconductor quantum dots - which are all hot topics in modern Photonics. A big emphasis is put on the description of surface plasmons and particle plasmons, where light can be extremely confined.

1. Introduction
1.1. Motivation
1.2. Literature
1.3. A bit of history
2. From Electromagnetic Theory to Optics
   2.1. What is Light?
   2.2. The Maxwell-equations
   2.3. The change of Light in Matter
   2.4. Wave equation and Helmholtz equation
   2.5. Waves in position space and frequency space
3. Fourier-Optics
   3.1. Introduction
   3.2. The Fourier-Transformation
   3.3. Linear Optical Systems
   3.4. Spatial frequency filters
   3.5. The Sampling Theorem
4. Wave-optical Light Propagation and Diffraction
   4.1. Paraxial light propagation by Gaussian beams
   4.2. Wave Propagation and Diffraction
   4.3. Evanescent waves
   4.4. Diffraction at thin Phase and Amplitude Objects
   4.5. Light Propagation in inhomogeneous Media
   4.6. Diffraction at gratings
   4.7. Acousto Optics
   4.8. Spatial Light Modulators
   4.9. Adaptive Optics and Phase Conjugation
5. Interference, coherence and holography
   5.1. Some Basics
   5.2. Interferometry
   5.3. Foundations of Coherence Theory
   5.4. Principles of Holography
6. Light Scattering and Plasmonics
   5.5. Scattering of light at particles
   5.6. Photon Diffusion
   5.7. Basics of Nonlinear Optics
   5.8. Fluorescence und Raman-scattering
   5.9. Fluorescing quantum dots
   5.10. Surface Plasmons and Particle Plasmons

### Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors.

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written
exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Concentration-Area Microsystems Engineering – Sensors and actuators

The Concentrations direction "Sensors and actuators" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyse- und Messmethoden für Dünnschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>11LE50MO-5117</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Module Type:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>3</td>
</tr>
<tr>
<td>SWS:</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile
# Lernziele / Learning target

The module gives an overview of all state-of-the-art measurement and analysis methods for thin films and nanoscopic structures. Special emphasis will be placed on the prospects and drawbacks of each method as well as on typical limits and potential measurement artifacts. Educational objective is to enable students to find a suitable and appropriate method to measure or detect a certain material property of interest.

# Inhalte Vorlesung / Content of the lecture

The treated measurement and analysis techniques include optical, electrical, chemical and structural methods which detect and probe material properties like morphology/shape, film thickness, crystallinity, chemical composition, trace impurities, bonding configurations, bandgap, etc. Namely methods like AFM, SEM / TEM, APT, SIMS, XPS, SE, PL, FTIR, Raman, XRD, C-V / I-V, RBS and many more will be dealt with.

# Zu erbringende Prüfungsleistung / Examination result

written or oral examination

# Benotung / Grading

The module grade is calculated from the result of the final examination.

# Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Bionische Sensoren / Bionic Sensors

Nummer: Number 11LE50MO-5701

Modulverantwortlicher: Responsible person Prof. Dr. G. Urban
Einrichtung: Organisational unit Chair for Sensors

Modultyp: Module Type Elective Module
Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture
Sprache: Language English

Empfohlenes Fachsemester:: Recommended term of study 2
ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 1 Lecture
Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 90 hours (14 Hours Full-time attendance course of study + 76 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

The aim of this module is a basic understanding of electrical, electrochemical and optical chemo- and biosensor principles as well as the basic knowledge of biological sensors. Principles of bioinspired system and the background of bionic learning from nature to realize microtechnological systems will be discussed. Basics of electrical charge transfer and information processes in biological systems will be presented.

Inhalte Vorlesung / Content of the lecture

The lecture bionic sensors deal with learning from nature to realize technical chemo- and
biosensors. Topics are:

- Biological sensors/receptors
- Charge transfer and information processes in biology
- Chemosensor, introduction
- Basics of electrochemistry
- Electrochemical potentiometric sensors
- Electrochemical amperometric sensors
- Gas sensors
- Biosensors

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsteilnahme / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsteilnahme / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
# Modul / Module

## Bionische Sensoren - Laboratory / Bionic Sensors - Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5702</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Kenntnisse der Inhalte in den Modulen Sensors, Bionic Sensors, BioMEMS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target

Students should gain hands on experience with several types of sensors the theory of which has been presented in the lectures “Sensors and Actuators” as well as “Sensorik und Aktorik”, and explained deeper in “Bionic Sensors” and “BioMEMS”.

**Inhalte Praktikum / Content of the laboratory**

Five experiments will be offered with selected types of sensors described in the lectures mentioned above. Students will work with the sensors, calibrate them, build up experiments and perform detection and measurements with the sensors under supervision of tutors.

**Zu erbringende Prüfungsleistung / Examination result**

Each student will have to write at least one report about one of the experiments she/he participated; during each experiment a written test and continuous discussions will take place; practical skills of the students in accordance with the basic theory will be observed and graded.

**Benotung / Grading**

The final module grade is determined from an average of the grades of the individual reports.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
The most successful microsystems to date have been based on silicon. Companies such as Bosch, Analog Devices, Texas Instruments, Sensirion, and other small and medium enterprises have built their success on this wise technological choice. The lecture deals with microsystems compatible with silicon foundry services and commercial silicon technologies, in particular CMOS technologies. It will offer a healthy mix of technology, physical sensor principles and operating techniques, and will be enriched with examples that made it into the market and others that have remained scientific visions. In tune with the progress of the
lecture material, home-work will be assigned, with the presentation and discussion of solutions by students during the course hours.

**Inhalte Vorlesung / Content of the lecture**

- Introduction
- Basic technologies
- Magnetic sensors
- Radiation sensors
- Stress sensors
- Inertial sensors
- Thermal sensors
- Chemical sensors
- Material parameters
- System integration

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Drahtlose Sensornetze / Wireless Sensor Networks

<table>
<thead>
<tr>
<th>Modul</th>
<th>/ Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nummer:</strong> Number</td>
<td>11LE13MO-1323</td>
</tr>
<tr>
<td><strong>Gültig seit:</strong> Valid since</td>
<td>01.04.2016</td>
</tr>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. C. Schindelhauer</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Networks and Telematics</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>German or English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Lectures + 1 Exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

### Arbeitsaufwand: Workload

180 hours

(56 hours Full-time attendance course of study + 124 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Lehramt an Gymnasien in Informatik, major subject
- Lehramt an Gymnasien in Informatik, additional major subject
- Lehramt an Gymnasien in Informatik, major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Sensors
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
  - Informationstechnik / Information Process Technologies

### Lernziele / Learning target
Students know the concrete application areas and requirements for wireless sensor networks and can apply standard methods of network layers.

### Inhalte Vorlesung / Content of the lecture

Difference between wireless sensor networks, mobile ad-hoc networks, and cellular networks, hardware architecture, software architecture in WSN, the physical layer, medium access 802.15.4 sensor Mac, routing, data centrality, information aggregation, network lifetime, energy harvesting, resilience in wireless sensor networks, localization

### Inhalte Übung / Content of the exercises

Modulation, Fourier transform, routing, localization, medium access, synchronization, network lifetime active participation in the exercises

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Jie Wu, Handbook on Theoretical and Algorithmic Aspects of Sensor
• Ad Hoc Networks and Peer-to-Peer Networks, Auerbach, 2005
## Drahtlose Sensorsysteme / Wireless Sensor Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5230</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
</tbody>
</table>

| Arbeitsaufwand: Workload | 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
**Lernziele / Learning target**

With the help of microelectronics many everyday objects have to be connected to realize visions like Pervasive Computing and Ambient Intelligence. Miniaturized, self-powered wireless sensor nodes - also discussed as eGrain or Smart Dust - will make an important contribution to the networking of various objects. Miniaturized sensor nodes for wireless sensor networks represent a design problem, which is characterized by a high degree of functional complexity combined with a significant realization diversity.

**Inhalte Vorlesung / Content of the lecture**

In the first part of the lecture behavioral and technological degrees of freedom of a wireless sensor system are presented and discussed intensively. Based on this, special systems such as tire pressure sensors, torque sensors and wireless sensor nodes for a logistics scenario will be discussed in detail.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bemotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5719</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible person:</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Organisational unit:</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td>Type:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Connected events:</td>
<td>Lecture</td>
</tr>
<tr>
<td>Language:</td>
<td>English</td>
</tr>
</tbody>
</table>

| Recommended term of study: | 3 |
| ECTS-points: | 6 |
| Lecture: | 2 |
| Regular cycle: | Only in the winter term |
| Workload: | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

The students know the essential concepts and fundamental equations of electrochemical theory. The participants from different subjects link together the knowledge from physical chemistry and several engineering disciplines to get a sound understanding of the classical electrochemical methods and electrochemical impedance spectroscopy. The students can apply their knowledge and understanding of the electrochemical methods to tasks in the
field of material science, microtechnology, Microsystems and energy application.

### Inhalte Vorlesung / Content of the lecture

- Electrochemical theory (cells, electrodes, fundamental equation and concepts)
- Instrumentation (focus on the interplay between electrochemistry and electronics/data acquisition), equipment (electrodes, cells), and electrolytes
- Classical methods (potentiometry, amperometry, CV, DPV, SWV, HDME, RDE, RRDE)
- Electrochemical impedance spectroscopy (EIS)
- Selected aspects: Material science (corrosion, hierarchical micro-/nanostructures)
- Selected aspects: Microtechnology (electrodeposition, failure mechanism)
- Selected aspects: Microsystems (electrochemical sensors and actuators)
- Selected aspects: Energy application (fuel cells, batteries, super caps)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

# Modul / Module

## Energiegewinnung / Energy Harvesting

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5703</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Design of Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (56 hours Full-time attendance course of study + 94 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

## Lernziele / Learning target

The students shall learn the basic principles of (micro) energy harvesting. Several energy conversion techniques, energy storage concepts and power management strategies are described in detail. By this the students shall become able to estimate the energy generation of different harvesting techniques and to work on the design of energy autonomous embedded systems. The importance of the system-level design in these systems is, in general, a central objective in this class.

## Inhalte Vorlesung / Content of the lecture
- Harmonical Oscillator (with bending beams)
- Piezoelectric Energy Harvesters
- Electrodynamical Energy Harvesters
- Electrostatic Energy Harvesters
- Non-Resonant Generators
- Thermoelectric Generators & Processes
- Thermomechanical Generators
- Capacitive Storages and Accumulators
- Step-up Converters and Advanced Step-up Converter Design
- Energy Harvesting Applications

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

## Flugregelung Laboratory / Flight Control Laboratory

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5222</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulfelder: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

The lab course includes topics as part of the HIGHWIND project (Simulation, Optimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of "Modelling and System Identification" and/or "Optimal Control and Estimation" are recommended.

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2 oder 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
### Lernziele / Learning target

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

### Inhalte Praktikum / Content of the laboratory

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles might be remote controlled airplanes with IMUs and GPS or quadrotors, and they might be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

### Zu erbringende Prüfungsleistung / Examination result

**Project work:**
- A working project result
- project documentation and oral presentation

### Benotung / Grading

The final module grade is determined from an average of the grades of the project documentation and the presentation.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Gassensorik / Gas Sensors

Nummer: Number

11LE50MO-5704

Modulverantwortlicher: Responsible person

Prof. Dr. J. Wöllenstein

Einrichtung: Organisational unit

Chair for Thin-film Gas Sensors

Modultyp: Module Type

Elective Module

Modulduer: Module duration

1 term

Zugehörige Lehrveranstaltungen: Connected events

Lecture

Sprache: Language

German

Empfohlenes Fachsemester: Recommended term of study

3

ECTS-Punkte: ECTS-points

3

SWS: Semester week hours

2 Lecture

Angebotsfrequenz: Regular cycle

only in the winter term

Arbeitsaufwand: Workload

90 hours

(32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target


Inhalte Vorlesung / Content of the lecture

In der Vorlesung werden Gassensoren, die auf unterschiedlichsten, chemischen und physikalischen Prinzipien basieren, vorgestellt und deren Funktionsweise, Herstellung und
Anwendung vermittelt. Gassensoren decken Massenmärkte mit sehr großen Stückzahlen ebenso ab, wie applikationsspezifische Sonderlösungen. Folgende wichtige Grundlagen für die Gassensorik werden diskutiert:

- Wechselwirkung Gas-Halbleiter, Adsorption, Elektrische Auswirkungen von adsorbierten Gasen
- Wärmeleitung u.-kapazität, Paramagnetismus von Gasen
- Schwingungs- und Rotationsspektren im IR, Druck- und Dopplerbreiterung, Linienformen
- Interferometer, Schwarzkörperstrahlung, Elektrochemie

Folgende Bauelemente und Messsysteme werden vorgestellt:

- Metalloxidgassensoren, Lambdasonde, Gassensitive Feldeffekttransistoren
- Wärmeleitfähigkeitsensoren, Pelistoren
- Paramagnetischer Sauerstoffsensor
- Optische Systeme (Laserspektrometer, Filterphotometer, Photoakustik, Wellenleiter), Fourier Transformations Infrarot Spectrometer
- Elektrochemische Sensoren, Elektronische Nasen

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikro systemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Begleitend zur Vorlesung wird ein Folien-Skriptum zur Verfügung gestellt.
### Modul / Module

**Mikroakustik / Microacoustics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5207</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target

Students will gain an understanding of the structure, operation and applications of micro acoustic devices. You will learn the basic methods for designing, modeling, for the optimization and for the production of these components. You know the functioning of bulk acoustic wave oscillators, surface acoustic wave components, as well as membrane and Bragg reflector-based thin film components.

You will be able to design and analyze simple "Finite Impulse Response" and "Infinite Impulse Response" filter. Students know the applications of micro acoustic components in...
wireless communications and in sensor technology.

**Inhalte Vorlesung / Content of the lecture**

The Micro Acoustics deals with the generation and manipulation of high-frequency (electro-) mechanical waves which enables the realization of high-frequency filters, sensors and actuators. The generation and manipulation is carried out via planar microstructures on piezoelectric materials on which these waves are performed.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Mikroakustik - Seminar / Microacustics - Seminar

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nummer: 11LE50MO-5226</td>
</tr>
<tr>
<td>Modulverantwortlicher: Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Elective Module</td>
</tr>
<tr>
<td>Moduldauer: 1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Seminar</td>
</tr>
<tr>
<td>Sprache: English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: 3</td>
</tr>
<tr>
<td>ECTS-Punkte: 3</td>
</tr>
<tr>
<td>SWS: 2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

The seminar micro acoustic offers the opportunity to work independently on a topic of micro acoustic and to present the results in a final presentation. As part of this work there will be built up based knowledge in specific areas of micro acoustic, and a scientific way of working is trained as well. The independent literature review is an integral part of the seminar paper. There is a personal attention of the seminar participants, which is essentially limited to the clarification of concrete, subject-specific issues. The seminar concludes with an oral exam in the form of the final presentations,
which are followed by a brief discussion.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
### Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5225</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). The course is self contained and can be followed by all students with sufficient background in mathematical systems and control theory. It is recommended not only to master students of engineering, but also to students of computer science, mathematics, and physics. An optimization course (e.g. „Applied Convex and Nonlinear Optimization“ or „Optimal Control and Estimation“) is an advantage, but not necessary.

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
Lernziele / Learning target

Aim of this module is to give both theoretical background and hands-on practical knowledge in theory and numerics for nonlinear model predictive control (NMPC). In particular, participants shall become able to formulate and to numerically solve NMPC problems with the help of modern computing tools.

Inhalte Vorlesung / Content of the lecture

The course covers all topics relevant for the theory and numerical solution of nonlinear model predictive control (NMPC) problems. It starts by recalling concepts from systems theory in continuous and discrete time as well as concepts from nonlinear optimization with equalities and inequalities, and the computation of derivatives. The major focus of the course is on the stability theory of NMPC and what impact it can have in control engineering practice. A second focus is on the numerical solution of nonlinear model predictive control and moving horizon estimation problems.

Inhalte Übung / Content of the exercises

All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python and CasADi (both open-source), and participants are recommended to bring a laptop. At the end of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards end of the course, after the written exam.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Bewertung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures

Nummer: Number
11LE50MO-5211

Modulverantwortlicher: Responsible person
PD Dr. A. Gombert

Einrichtung: Organisational unit
IMTEK

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlenes Fachsemester:: Recommended term of study
3

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
• Bachelor of Science in Embedded Systems Engineering
• Master of Science in Embedded Systems Engineering
  o Circuits and Systems
  o Sensors and Actuators
  o Personal Profile
• Master of Science in Informatik
  o Application area Mikrosystemtechnik
• Master of Science in Mikrosystemtechnik
  o Circuits and Systems
  o Photonics
  o Sensors and Actuators
  o Personal Profile
• Master of Science in Microsystems Engineering
  o Circuits and Systems
  o Photonics
  o Sensors and Actuators
  o Personal Profile

Lernziele / Learning target

The objective of this module is learning the fundamentals of technics and physics with respect to the interaction of electro-magnetic waves with predominantly periodically...
structured matter. The students will be enabled to predict the qualitative optical properties of micro and nano structured materials with the taught methods. The superior learning target is to master the fundamental capabilities to design diffractive optical elements and optical elements based on subwavelength structures as well as to know their respective technical applications. The students will obtain the engineering know-how for micro and nano optical elements as used in micro systems technology.

Inhalte Vorlesung / Content of the lecture

Micro and nano structures have optical properties that differ from macroscopic bodies. The interaction between incident light or more generally incident electromagnetic radiation may lead to a modification of the propagation direction, the polarisation, and the spectral signature of absorption, reflection or transmission. In micro systems or similar technologies these phenomena can be used on purpose or need to be considered when manufacturing micro and nano structures. In this lecture we will work on the theoretical fundamentals as well as on selected applications.

Topics:
- Calculating with complex amplitudes
- Energy transfer at boundaries
- Two beam interference
- Huygens’ principle
- Fresnel’s zone construction
- Introduction into Fourier optics
- Kirchhoff-Fresnel diffraction integral
- Fresnel diffraction
- Fraunhofer diffraction
- Introduction into diffraction gratings
- Spectroscopic gratings
- Theory and applications of subwavelength gratings
- Photonic crystals
- Resonant structures in metals
- Production technologies for micro structures with optical functions

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- E. Hecht: Optics, Addison-Wesley, 1989
Modulhandbuch M.Sc. Mikrosystemtechnik – Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking

Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking

Nummer: Number 11LE50MO-5219

Modulverantwortlicher: Responsible person Prof. Dr. A. Rohrbach
Einrichtung: Organisational unit Chair for Bio- and Nanophotonics

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlenes Fachsemester:: Recommended term of study 4
ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 3 Lecture + 2 Exercises
Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 180 hours (70 Full-time attendance course of study + 110 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

Optical traps and optical micro-manipulation techniques do have the potential to play a key role in future micro- and nanosystems in conjunction with the life sciences. In this lecture the students should learn what is doable with optical forces, where physical limits are and what...
is limited by nowadays technology. Besides fascinating fundamental research various applications related to biology or fluctuation based systems are presented. The lecture is manifold and teaches basics in optics, statistical physics and biology/biophysics.

### Inhalte Vorlesung / Content of the lecture

- 25. Introduction
- 26. Light - Information carrier and actor
- 27. About microscopy
- 28. Light scattering
- 29. Optical forces
- 30. Tracking beyond the uncertainty
- 31. Brownian motion and calibration techniques
- 32. Photonic force microscopy
- 33. Applications in cell biophysics
- 34. Time- multiplexing and holographic optical traps
- 35. Applications in microsystems technology
- 36. Applications in nanotechnology

### Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of
2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.</td>
</tr>
</tbody>
</table>
**Modulhandbuch M.Sc. Mikrosystemtechnik – Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques**

### Modul / Module

**Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques**

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5710</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. K. Buse</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Optical Systems</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachsemester:** Recommended term of study | 2 |
| **ECTS-Punkte:** ECTS-points | 3 |
| **SWS:** Semester week hours | 2 Seminar |
| **Angebotsfrequenz:** Regular cycle | Only in the summer term |
| **Arbeitsaufwand:** Workload | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

The students gain knowledge about different optical measurement techniques for shape determination of objects or for material characterization. They achieve a deeper understanding of the physical background. Consequently, the participants are able to estimate the fundamental and technological limitations of the methods presented. This enables the students to select an appropriate optical measurement technique for a given task. Furthermore, the participants get trained in preparing and presenting excellent talks.
Inhalte Seminar / Content of the seminar

During the first meeting the organizers will present a list of topics from which each active participant of the seminar can select one. For each topic literature will be provided. Starting with this material the active participants of the seminar will familiarize themselves with the content. This will be done by discussions as well as by further literature search. Based on the accumulated knowledge, an outline for talks will be made and finally the viewgraphs will be prepared. Then the talk will be presented in the seminar. Typical duration of the talk is 30 minutes. After the talk there will be a discussion about the content. And as a second part of the discussion technical issues of the talk will be analyzed. Finally, a short written summary of the talk will be prepared. Talks can be given in German or English.

This semester, the following topics are available:
- 3d-shape determination
- Optical microresonators for sensing
- Terahertz waves for material characterization
- Photoacoustic spectroscopy
- Laser spectroscopy
- Fluorescence spectroscopy
- and more

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Befl evaluation / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

The advisor will provide literature as a starting package.
Optische Mikrosensoren / Optical Micro-Sensors

Nummer: 11LE50MO-5711

Modulverantwortlicher: Prof. Dr. A. Brandenburg
Einrichtung: IMTEK

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Vorlesung
Sprache: German

Empfohlenes Fachsemester: 2
ECTS-Punkte: 3

SWS: 2 Lecture
Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

Kenntnis der Prinzipien miniaturisierter optischer Sensoren, Vertiefung bei den Gebieten Wegsensorik, Drehratensensoren sowie chemische und biochemische Sensoren.

Inhalte Vorlesung / Content of the lecture

- Vorbereitende Inhalte: Grundlagen der Optik (kurze Wiederholung), Lichtwellenleiter.
- Optische Grundlagen für die Sensorik: Interferometrie, Sagnac-Effekt, Spektroskopie, Fluoreszenz.
- Detaillierte Darstellung der Funktion und der technologischen Realisierung von
**Modulhandbuch M.Sc. Mikrosystemtechnik – Optische Mikrosensoren / Optical Micro-Sensors**

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• G. Schröder: Technische Optik, Vogel-Verlag, Würzburg 1980</td>
</tr>
<tr>
<td>• T. Tamir (Hrsg.): Guided wave optoelectronics, Springer-Verlag 1988</td>
</tr>
<tr>
<td>• W. Schmidt: Optische Spektroskopie, VCH Verlagsgesellschaft Weinheim 1994</td>
</tr>
</tbody>
</table>
## Modul / Module

### Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5712</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S. Glunz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Photovoltaic Energy Conversion (INATECH)</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge of semiconductor physics and technology.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td></td>
<td>(28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

### Lernziele / Learning target

This module gives a general overview of the components of photovoltaic energy systems.
and the chances of this renewable energy.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung  / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>To be admitted to the final examination, the lecture at each lecture date must be visited. Unexcused absence leads to a non-admission to the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung  / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung  / Course Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to attend the lecture regularly in order to be admitted to the final module exam.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung  / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
Modulhandbuch M.Sc. Mikrosystemtechnik – Photovoltaic Energy Conversion for Engineers II

Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for Engineers II

**Nummer:** 11LE50MO-5718

**Modulverantwortlicher:** Prof. Dr. S. Glunz

**Einrichtung:** Chair for Photovoltaic Energy Conversion (INATECH)

**Modultyp:** Elective Module

**Modulverantwortlicher:**

Prof. Dr. S. Glunz

**Einrichtung:**

Chair for Photovoltaic Energy Conversion (INATECH)

**Modultyp:**

Elective Module

**Moduldauer:** 1 term

**Zugehörige Lehrveranstaltungen:**

- Lecture

**Sprache:** English

**Empfohlene Voraussetzungen:**

- Photovoltaic Energy Conversion for engineers I
- Halbleiterphysik/Semiconductor Physics

**Empfohlenes Fachsemester:**

Recommended term of study: 2

**ECTS-Punkte:**

ECTS-points: 3

**SWS:**

Semester week hours: 2 Lecture

**Angebotsfrequenz:**

Regular cycle: Only in the summer term

**Arbeitsaufwand:**

Workload: 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Mikrosystemtechnik
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

**Lernziele / Learning target**

The focus of the first part of this module series "Photovoltaic Energy Conversion for engineers II" was on the fundamentals of solar cells and on the technology of crystalline silicon solar cells. This second part "Photovoltaic Energy Conversion for engineers II" focusses on alternative photovoltaic technologies, system aspects, grid integration and the
The lecture "Photovoltaic Energy Conversion II" starts with a short wrap-up of the contents of the preceding lecture and then focuses on:

- Thin-film PV technologies (CIS, CdTe, ...)
- Organic solar cells
- Perovskite solar cells
- Multijunction solar cells (Tandem)
- III/V-based PV and concentrator applications
- Photonics for solar cells (upconversion, ultra light rapping ...)
- System technology (inverters, storage)
- Grid integration (smart grids, ...)
- Economy of Photovoltaics

The students have to attend the lecture regularly in order to be admitted to the final module exam.

### Written or Oral Examination

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

### Course Achievement

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Grading

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

### Weight of Examination Result

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its
ECTS-points in the calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Würfel, Physik der Solarzelle, Spektrum - Akademischer Verlag 2000</td>
</tr>
<tr>
<td>A. Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner 1997</td>
</tr>
<tr>
<td>M.A. Green, Solar Cells, University of New South Wales 1982</td>
</tr>
<tr>
<td>Konrad Mertens, Photovoltaik, Hanser 2011</td>
</tr>
<tr>
<td>Jenny Nelson, The physics of solar cells, Imperial College Press 2008</td>
</tr>
</tbody>
</table>
Piezoelektrische und dielektrische Wandler / Piezoelectric and dielectric transducers

Nummer: 11LE50MO-5713

Modulverantwortlicher: Prof. Dr. P. Woias
Einrichtung: Chair for Design of Microsystems

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen: Mechanics and electronics should be known from bachelor studies

Empfohlenes Fachsemester: 2
ECTS-Punkte: 3

SWS: 2 lecture + 1 exercises
Angebotsfrequenz: Only in the summer term

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

You will...
- be able to explain the physical effects that lead to electro-mechanical coupling
- be able to use the linear coupled theory to model dielectric and piezoelectric transducers
- be able to describe nonlinear effects and some ways to model them
• know several applications of dielectric and piezoelectric transducers and their advantages and disadvantages

**Inhalte Vorlesung / Content of the lecture**

• Introduction to Piezoelectrics (material science)
• Linear theory of Piezoelectrics
• Nonlinear Effects, high field effects, hysteresis
• Other transduction mechanisms (Electrets, Electrostriction)
• Applications

**Inhalte Übung / Content of the exercises**

To qualify for the exam at least one of the exercise tasks must be solved on the chalk board during an exercise session.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benuoting / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
Quantenmechanik für Ingenieure / Quantum mechanics for engineers

**Modul / Module**

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Responsible person</td>
<td>Chair for Microsystem Materials</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module Type</td>
<td>Module duration 1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
</tr>
<tr>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Knowledge in Semiconductor Physics or Physical Electronics</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: | 2 |
| Recommended term of study | ECTS-Punkte: |
| ECTS-points | 6 |
| SWS: | 2 lecture + 2 exercises |
| Semester week hours | Angebotsfrequenz: |
| Regular cycle | Only in the summer term |
| Arbeitsaufwand: | 180 hours |
| Workload | (56 hours Full-time attendance course of study + 124 hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**

The goal is to introduce the students to the main effects of quantum mechanics relevant in technical micro and nano devices. Current semiconductor components in which quantum
Mechanics plays a role are discussed in depth. The course successively develops the basic mathematical methods required to solve one, two and three-dimensional problems. The understanding is deepened by practical exercises.

Inhalte Vorlesung / Content of the lecture

- Introduction: Historical overview, unsolved problems at the beginning of the 20th century, probability amplitudes, uncertainty relation
- Wave mechanics: Schrödinger equation, separation of variables, free particle, reflection at wall, potential step, transfer matrix method, wave packets
- Tunneling: Principle, semiconductor tunneling devices, potential barriers, WKB approximation, triangular potential wall
- Bound states, resonances, and band structure: Potential well, tunneling between wells, infinite series of potential wells
- Single electron transistors: Double-junction SETs, Coulomb barrier, Coulomb staircase, gate-biased SETs, single-electron turnstile, single-electron pumps

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Lecture notes.
Modul / Module

Rennautoregelung – Laboratory / Race Car Control Laboratory

Nummer: 11LE50MO-5224

Modulverantwortlicher: Prof. Dr. M. Diehl
Einrichtung: Chair for Systems Control and Optimisation

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Laboratory
Sprache: English

Empfohlene Voraussetzungen:
The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

Empfohlenes Fachsemester: 3 ECTS-Punkte: 6
SWS: 4 Laboratory Angebotsfrequenz: Each term
Arbeitsaufwand: 180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
**Lernziele / Learning target**

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

**Inhalte Vorlesung / Content of the lecture**

Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controlling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer.

The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

**Zu erbringende Prüfungsleistung / Examination result**

Project work:
- A working project result
- Project documentation and oral presentation

**Benotung / Grading**

The final module grade is determined from an average of the grades of the project work.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5714</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Design of Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 5 |
| SWS: Semester week hours | 2 lecture + 2 exercises |
| Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitssaufwand: Workload | 150 hours (56 hours Full-time attendance course of study + 94 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / Learning target

Das Modul vermittelt grundlegendes Wissen zur elektronischen Schaltungstechnik verschiedener Mikrosensoren und Mikroaktuatoren. Es werden in einer Abfolge von Kapiteln zunächst die Grundlagen einiger wesentlicher elektronischer Bauelemente und Funktionsgruppen vermittelt. Anschließend werden kapitelweise mehrere Sensor- und
Aktormechanismen kurz vorgestellt, gefolgt von einer Erläuterung der wichtigsten Schaltungskonzepte für ihren Betrieb.

### Inhalte Vorlesung / Content of the lecture

Die Vorlesung ist in folgende Kapitel gegliedert:

- Einführung in elektronische Bauelemente und Funktionsblöcke (Diode, Bipolartransistor, Stromquellen, Stromspiegel, Bandgap-Referenz, Operationsverstärker)
- Stromliefernde Sensoren (Photodiode, amperometrische Elektrode)
- Spannungsliefernde Sensoren (Ionenempfindlicher Feldeffekttransistor)
- Resistive Sensoren nach dem Wheatstone-Brückenprinzip (Druck, Beschleunigung)
- Kapazitive Sensoren (Druck, Beschleunigung, Feuchte)
- Kapazitive Aktoren (elektrostatisch, piezo)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Modul / Module

## Spektroskopische Methoden / Spectroscopic Methods

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5717</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Thin-film Gas Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

## Lernziele / Learning target


## Inhalte Vorlesung / Content of the lecture

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.
Modulhandbuch M.Sc. Mikrosystemtechnik – Thermoelektrik / Thermoelectric

Thermoelektrik / Thermoelectric

Nummer: 11LE50MO-5715
Modulverantwortlicher: Prof. Dr. J. Wöllenstein
Einrichtung: Chair for Thin-Film Gas Sensors
Modultyp: Elective Module
Moduldauer: 1 term
Zugehörige Lehrveranstaltungen: Lecture
Sprache: German
Empfohlene Voraussetzungen: Basic knowledge physics, electrical engineering, microsystem technology and sensor technology

Empfohlenes Fachsemester: 5
ECTS-Punkte: 3
SWS: 2 Lecture
Angebotsfrequenz: Only in the winter term
Arbeitsaufwand: 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / Learning target

Das Ziel des Moduls ist die Vermittlung der physikalischen, chemischen, elektrischen Funktionsweise thermoelektrischer Bauelemente und Systeme. Dabei werden aufbauend auf den vermittelten Grundlagen typische Materialsysteme, Modultechnologien und Anwendungen vorgestellt. Die Studierenden sollen den Zusammenhang zwischen der
Wirkungsweise, Modul- und Systemdesign, Fertigungsprozessen und dem Einsatz thermoelektrischer Systeme wie Thermogeneratoren, Peltier-Elemente und Thermocouples erlernen.

### Inhalte Vorlesung / Content of the lecture


### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Begleitend zur Lecture werden die verwendeten Folien zur Verfügung gestellt.
Concentration-Area Microsystems Engineering – Personal profile

The Concentrations direction "Circuits and systems" is one of several Concentration directions in the Master of Science in Microsystems Engineering. Students who have chosen this direction, it must complete minimum 9 ECTS points in this direction.

### Modul / Module

**Analyse- und Messmethoden für Dünnschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5117</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

| 5 | ECTS-Punkte: ECTS-points | 3 |
| 2 lecture | Angebotsfrequenz: Regular cycle | Only in the winter term |

**Arbeitsaufwand: Workload**

| 90 hours | (32 Hours Full-time attendance course of study + 58 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile
### Lernziele / Learning target

The module gives an overview of all state-of-the-art measurement and analysis methods for thin films and nanoscopic structures. Special emphasis will be placed on the prospects and drawbacks of each method as well as on typical limits and potential measurement artifacts. Educational objective is to enable students to find a suitable and appropriate method to measure or detect a certain material property of interest.

### Inhalte Vorlesung / Content of the lecture

The treated measurement and analysis techniques include optical, electrical, chemical and structural methods which detect and probe material properties like morphology/shape, film thickness, crystallinity, chemical composition, trace impurities, bonding configurations, bandgap, etc. Namely methods like AFM, SEM / TEM, APT, SIMS, XPS, SE, PL, FTIR, Raman, XRD, C-V / I-V, RBS and many more will be dealt with.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Oberflächenanalyse / Surface Analysis

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5606-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for the Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

## Lernziele / Learning target

XPS, TEM, FTIR, UPS, SEM, AFM, SPR, GIR, ATR, STM?? Got it? The performance of microsystems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in microsystems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of microsystems engineering.

## Inhalte Vorlesung / Content of the lecture
The techniques presented are grouped into three general topics which are imaging of surfaces (electron microscopy, scanning probe techniques), chemical analysis (XPS, SIMS, FTIR) of the composition of surfaces and methods for the determination of thicknesses (Ellipsometry, XRR, Surface Plasmon Spectroscopy) of layers. General topics from the surface sciences such as adhesion, wetting, and adsorption processes are also presented together with the techniques.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Various materials are available on the website.
Module / Module

Ausgewählte Problemstellung in Biosignalverarbeitung / Selected Problems in Biosignal Processing

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5303</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Hofmann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Faculty of Medicine</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaureurance: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlene Voraussetzungen: Recommended requirements

Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one „programming“ language like Python (preferably), Matlab (or Octave) or even IDL (not supported).

Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

ECTS-Punkte: ECTS-points

<table>
<thead>
<tr>
<th>2 Lecture + 1Übung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
</tr>
<tr>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

Arbeitsaufwand: Workload

<table>
<thead>
<tr>
<th>90 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(42 Hours Full-time attendance course of study + 48 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Participants will learn to interpret and analyze biological signals of high bandwidth. They will
- gain a deep knowledge of feature extraction methods,
- utilize selected classification methods and
- decision making methods.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
## Modul / Module

### Bauelemente und Schaltungen der Leistungselektronik / Power Electronic Circuits and Devices

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-9010</th>
<th>Gültig ab: Valid from</th>
<th>01.04.2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Ambacher, PD Dr. Quay</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Compound Semiconductor Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Moduldaener Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lectures + 2 exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering

### Lernziele / Learning target

The students will be enabled to understand materials, concepts, functioning, and design of modern power devices, circuits, and converter systems suitable for microscopic and macroscopic energy systems. This includes the understanding of hair cells and engine proteins as well as solar energy photovoltaic converters and engines in traffic. The basic concepts of power conversion (AC theory), of passive and active semiconductor devices, high-voltage operation, converter-, and control concepts, device protection, and aspects of system and power network theory are treated. The students will be competent to analyze, understand the fabrication, and design passive and active power devices such as MOSFET, Insulated Gate Bipolar IGBT, Junction FETs (JFET), thyristors, and circuits, full converter functions, integration, and analyze full system concepts. Circuits and system concepts for
power conversion, such as half and full bridges, current controls, aspects high voltage operation, and design for robustness are presented, and several examples are discussed in detail.

### Inhalte Vorlesung / Content of the lecture

The lecture deals with the fundamentals and concepts of power devices and circuits. It comprises three parts: fundamental power conversion-concepts with focus on DC-DC and – AC conversion, more complex power circuitry, and actual power conversion systems. At the interface of modern electronics, circuit design, and control theory, advanced analysis, fabrication, and characterization techniques are introduced in order to bridge the gap from modern power conversion to the understanding of systems and network systems with all aspects of power conversion. The methodologies of power-analysis, design of circuits, complex power flow, processing of devices, their modelling and their characterization are introduced along with the demonstration of their relevance to real power-components and - systems. Typical applications include DC-DC conversion for server systems, photovoltaic power conversion, application to microscopic power converters, and high-voltage windcraft systems.

### Inhalte Übung / Content of the exercises

Written exercises have to be done. For the successful completion of the exercise 50% of the work has to be completed successfully.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral final exam

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

## Bioactive Polymer Surfaces

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5321</th>
<th>Valid since: Valid since</th>
<th>02.09.2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible person</td>
<td>Prof. Dr. Rühe</td>
<td>Chair for the Chemistry and Physics of Interfaces</td>
<td></td>
</tr>
<tr>
<td>Module Type</td>
<td>Elective Module</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Connected events</td>
<td>Lecture</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Recommended requirements</td>
<td>- General knowledge of organic chemistry</td>
<td>- General knowledge of macromolecular chemistry</td>
<td></td>
</tr>
<tr>
<td>Recommended term of study</td>
<td>3</td>
<td>ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>Semester week hours</td>
<td>2 Lecture</td>
<td>Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The aim of this module is to enable you to
- understand the basic physical properties of polymer surfaces
- get to know fabrication processes of polymer surfaces
- understand different kinds of bioactivity, their mechanisms, and their applications
- understand the interaction of polymer surfaces with organisms
### Inhalte Vorlesung / Content of the lecture

- Surface properties
- Synthesis of functional polymer surfaces: non-covalent and covalent attachment, coating of surfaces with polymers, microstructuring of polymer surfaces
- Interaction of polymer surfaces with biomolecules and cells
- Antimicrobial, protein-resistant and antifouling polymer surfaces, DNA immobilization on surfaces, DNA origami, immunoactive polymer surfaces, etc.
- Special applications

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Literature recommendations will be provided with the lecture material.
Bioaktive Polymeroberflächen mit Seminar / Bioactive Polymer Surfaces with seminar

**Nummer: Number** 11LE50MO-5322

**Gültig seid: Valid since** 02.09.2015

**Modulverantwortlicher: Responsible person** Prof. Dr. Rühe

**Einrichtung: Organisational unit** Chair for the Chemistry and Physics of Interfaces

**Modultyp: Module Type** Elective Module

**Moduldauer: Module duration** 1 term

**Zugehörige Lehrveranstaltungen: Connected events** Lecture and exercises

**Sprache: Language** English

**Empfohlene Voraussetzungen: Recommended requirements**
- General knowledge of organic chemistry
- General knowledge of macromolecular chemistry

**Empfohlenes Fachsemester:: Recommended term of study** 3

**ECTS-Punkte: ECTS-points** 5

**SWS: Semester week hours** 2 Lecture + 1 exercises

**Angebotsfrequenz: Regular cycle** Only in the winter term

**Arbeitsaufwand: Workload** 150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

The aim of this module is to enable you to
- understand the basic physical properties of polymer surfaces
- get to know fabrication processes of polymer surfaces
- understand different kinds of bioactivity, their mechanisms, and their applications
- understand the interaction of polymer surfaces with organisms
- learn to work with original research papers

**Inhalte Vorlesung / Content of the lecture**

- Surface properties
- Synthesis of functional polymer surfaces: non-covalent and covalent attachment, coating of surfaces with polymers, microstructuring of polymer surfaces
- Interaction of polymer surfaces with biomolecules and cells
- Antimicrobial, protein-resistant and antifouling polymer surfaces, DNA immobilization on surfaces, DNA origami, immunoactive polymer surfaces, etc.
- Special applications

**Inhalte Übung / Content of the exercises**

In this exercise class, you will work with original research papers and write a short review of selected topics.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course achievement**

The tutorials help the students to get a more in-depth and thorough understanding of the topic. Students will work with original research papers and have to write a short review of a selected topic which will be evaluated.

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Literature recommendations will be provided with the lecture material.
### Biobrennstoffzelle und Bioelektrochemische Systeme / Biofuel Cells and Bioelectrochemical Systems

#### Modulverantwortlicher:
Prof. Dr. R. Zengerle

#### Einrichtung:
Chair for MEMS Applications

#### Modultyp:
Elective Module

#### Modulverantwortlicher:
Prof. Dr. R. Zengerle

#### Zugehörige Lehrveranstaltungen:
Lecture and Seminar

#### Sprache:
German

#### Empfohlene Voraussetzungen:
High school education in mathematics and natural sciences

#### Empfohlenes Fachsemester:
4 oder 5

#### ECTS-Punkte:
3

#### SWS:
1 Lecture + 1 Seminar

#### Angebotsfrequenz:
Each term

#### Arbeitsaufwand:
90 hours (28 oder 32 Hours Full-time attendance course of study + 58 oder 62 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture

In der Vorlesung wird eine Einführung in elektrochemische Energiewandler und speziell in bioelektrochemische Systeme gegeben. Behandelt werden schwerpunktmäßig die Punkte theoretischer Hintergrund und Funktions-Prinzipien, Design, Anwendungsbeispiele, und Methoden zur Charakterisierung.

### Inhalte Seminar / Content of the seminar

Im Seminar halten die Studierenden Vorträge zu aktuellen Themen aus den Bereichen Biobrennstoffzelle, Bioenergie und regenerative Energieversorgung. Im praktischen Teil werden Biobrennstoffzellen aufgebaut und elektrochemisch charakterisiert. Dieser Teil wird mit einer Auswertung und Diskussion der erhaltenen Ergebnisse abgeschlossen. Um zur Abschlussprüfung zugelassen zu werden, muss die schriftliche Ausarbeitung erfolgreich bestanden sein.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The
grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Begleitend zur Vorlesung wird ein Skriptum zur Verfügung und regelmäßig aktualisiert.
### Biochiptechnologien / Biochip Technologies

**Nummer: Number** 11LE50MO-5402

**Modulverantwortlicher: Responsible person** Prof. Dr. J. Rühe

**Einrichtung: Organisational unit** Chair for the Chemistry and Physics of Interfaces

**Modultyp: Module Type** Elective Module

**Moduldauer Module duration** 1 term

**Zugehörige Lehrveranstaltungen: Connected events** Lecture

**Sprache: Language** English

**Empfohlenes Fachsemester:: Recommended term of study** 4

**ECTS-Punkte: ECTS-points** 3

**SWS: Semester week hours** 2 Lecture

**Angebotsfrequenz: Regular cycle** Only in the summer term

**Arbeitsaufwand: Workload** 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target

For modern Life sciences and molecular diagnostics Biochip technologies play a key role for miniaturization and parallelization of analysis. They combine different methods for microstructuring surfaces, for immobilizing biomolecules and read-out technologies. Here, all the aspects and tools for the development of modern bioanalytical surfaces and applications will be addressed in this lecture.

### Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Surface modifications, techniques and components
- Manufacturing biochips
- State of the art, an overview
- Nucleic acid based biochip analytics
- Protein biochip technologies

Complex biochip applications

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various materials are available on the website <a href="http://www.cpi.uni-freiburg.de/">http://www.cpi.uni-freiburg.de/</a></td>
</tr>
</tbody>
</table>
**Modulhandbuch M.Sc. Mikrosystemtechnik – Biomedizinische Messtechnik I / Biomedical Instrumentation I**

---

**Modul / Module**

**Biomedizinische Messtechnik I / Biomedical Instrumentation I**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5301</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

| 2 |

**ECTS-Punkte: ECTS-points**

| 3 |

**SWS: Semester week hours**

| 2 lecture + 1 exercises |

**Angebotsfrequenz: Regular cycle**

| Only in the summer term |

**Arbeitsaufwand: Workload**

| 90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study) |

---

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

---

**Lernziele / Learning target**

The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to record electrical signals out of the human body and to understand and the technical and medical background of the most important (electrical) diagnosis methods.

The module teaches the students of Microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical instrumentation with respect to bioelectrical signals. The students will be enabled to design and develop fundamental amplifier circuits and learn about the physiological effects of electrical hazards and will be able to apply basic mechanisms and measures to provide electrical safety. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering.
**Inhalte Vorlesung / Content of the lecture**

The course introduces different aspects of the recording of bioelectrical signals starting with the nerve and including amplifier design. It presents the most important medical diagnosis methods in the field of bioelectrical signals. In detail, the following topics will be covered:

- Origin of bioelectrical signals
- Electrochemistry of electrodes
- Acute and chronic applications of electrodes
- Recording and amplification of bioelectrical signals
- Interference and artefacts
- Bioelectrical signals of peripheral nerves and the muscle
- Electrical signals of the heart (ECG)
- Cardiac pacemakers and implantable defibrillators
- Technical safety of medical devices

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination systems.

**Inhalte Übung / Content of the exercises**

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

**Zu erbringende Prüfungsleistung / Examination result**

- Written or oral examination
- Graded exercises/practical exercises

**Benotung / Grading**

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual copies of the slides will be delivered accompanying to the lectures. Further reading material</td>
</tr>
<tr>
<td><strong>English</strong></td>
</tr>
<tr>
<td><strong>German</strong></td>
</tr>
<tr>
<td>• Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005</td>
</tr>
</tbody>
</table>
### Biomedizinische Messtechnik II / Biomedical Instrumentation II

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5302</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

### Lernziele / Learning target

The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to acquire non-electrical measurement categories out of the human body and to impart knowledge about the technical and medical background of the most important imaging methods in medicine. The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical terms with respect to cardiovascular diagnosis and imaging techniques. The students will get an overview of the application areas of the different methods and the technical background of the underlying measurement principles and measurement systems. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering.
Inhalte Vorlesung / Content of the lecture

The course introduces methods to acquire non electrical cardiovascular parameters as well as the most important medical imaging techniques.

- Measurement of cardiovascular parameters: blood pressure, physiology, pressure, measurement according to Riva Rocci & oscillometric
- Measurement of cardiovascular parameters: blood flow, electromagnetic measurement principle
- Measurement of cardiovascular parameters: blood flow, ultrasound measurement principle
- Imaging techniques: x-ray
- Imaging techniques: systems theory of imaging systems, digital signal processing
- Imaging techniques: computer tomography
- Biological effect of ionizing radiation / dosimetry
- Imaging techniques in nuclear medicinal diagnosis
- Imaging techniques: ultrasound
- Imaging techniques: thermography and impedance tomography
- Imaging techniques: electrical sources, optical tomography, endoscopy
- Imaging techniques: MR tomography
- Imaging techniques: molecular imaging

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Inhalte Übung / Content of the exercises

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual copies of the slides will be delivered accompanying to the lectures. Further reading material:</td>
</tr>
<tr>
<td><strong>English</strong></td>
</tr>
<tr>
<td><strong>German</strong></td>
</tr>
<tr>
<td>• Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005</td>
</tr>
</tbody>
</table>
### Modul / Module

**Biomedizinische Messtechnik - Laboratory / Biomedical Instrumentation - Laboratory**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5304</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
<td>Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen:</td>
<td>Mandatory preconditions</td>
<td>The successful participation in the modules &quot;Biomedizinische Messtechnik I / Biomedical Instrumentation I&quot; is a prerequisite for admission to this module.</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Basic knowledge in mathematics and natural sciences</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS:</td>
<td>Semester week hours</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>Workload</td>
<td>90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

### Lernziele / Learning target

Learning targets and scientific objectives are the acquisition of scientific knowledge and practical skills to independently record bioelectrical signals and apply and transfer this theoretical knowledge of signal acquisition and noise and artefact suppression into practical
applications. This module teaches the students the recording of bioelectrical signals from
the human body, the handling of surface electrodes, the development of simple electronic
circuits and the fundamentals of digital signal processing of bioelectrical signals with the
help of Software packages to develop automatic signal acquisition routines.

### Inhalte Praktikum / Content of the laboratory

Within this laboratory, practical exercises will be performed in small groups with a maximum
of three participants. In the first part of the course program, diagnostic measures like blood
pressure, signals from the heart (electrocardiogram) and muscle (electromyogram), and the
determination of the motor nerve conduction velocity will be learned. Characteristic
parameters will be extracted from the signals as basis for diagnosis in medicine.
The students design and develop independently an electronic amplifier circuit to record
muscle signals as well as a graphical user interface to display these signals and control a
technical artefacts (e.g. a cursor on the screen or a small robotic hand) with these muscle
signals. The performance of this simple man-machine-interface will be eventually evaluated
under real-life conditions.

### Zu erbringende Prüfungsleistung / Examination result

Several written tests as well as evaluation of a written documentation concerning the
development of „Men-Computer-Interface“.
For the practical exercises, attendance is mandatory. It is possible to ask for auxiliary dates
and to have access to the chair’s labs outside the exercise sessions.

### Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports
and tests.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

BioMEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlene Voraussetzungen: Recommended preconditions

Previous knowledge from the courses "Sensors" or "Sensorik/Aktorik".

Empfohlenes Fachsemester:: Recommended term of study

2

ECTS-Punkte: ECTS-points

3

SWS: Semester week hours

1 Lecture

Angebotsfrequenz: Regular cycle

Only in the summer term

Arbeitsaufwand: Workload

90 hours

(14 Hours Full-time attendance course of study + 76 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Effective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

The students will obtain knowledge in different topics of microsystems comprising biological components as well as microsystems for biological applications. They will obtain a profound understanding of the underlying biological and microsystems concepts by several selected examples. The final learning objective is the understanding of connections between biology, biochemistry, microfluidics, medicine and micro engineering as well as the application of this understanding to future topics in this field.
<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Introduction</td>
</tr>
<tr>
<td>• Biochemistry and cells</td>
</tr>
<tr>
<td>• Cell culture monitoring</td>
</tr>
<tr>
<td>• Tissue engineering and cell handling</td>
</tr>
<tr>
<td>• Cell mechanics</td>
</tr>
<tr>
<td>• Single cell analysis</td>
</tr>
<tr>
<td>• Sensors based on microorganism</td>
</tr>
<tr>
<td>• Immunoassays and immunosensors</td>
</tr>
<tr>
<td>• DNA and RNA analytics on chip</td>
</tr>
<tr>
<td>• Implantable devices, in vivo sensors</td>
</tr>
<tr>
<td>• “Wellness MEMS”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
Modulhandbuch M.Sc. Mikrosystemtechnik – BioMST 1 –
Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 1 –
Biotechnological Tasks for Microsystems Technology

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioMST 1 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 1 – Biotechnological Tasks for Microsystems Technology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5315</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 oder 64 hours Full-time attendance course of study + 116 oder 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target

Die Studierenden gewinnen grundlegende Kenntnisse über das Spektrum der Biotechnologie und in den Teilbereichen der Mikro- und Molekularbiologie. Anhand ausgewählter Beispiele aus verschiedenen Bereichen der Biotechnologie gewinnen Sie ein Verständnis dafür wie durch den Einsatz der Mikrosystemtechnik mikro- und molekularbiologische Probleme vorteilhaft gelöst werden können. Ferner erhalten die

Laboratory „BioMST 1: Grundtechniken der Molekularbiologie:

### Inhalte Vorlesung / Content of the lecture

Anhand ausgewählter Beispiele wird gezeigt, wie durch den Einsatz der Mikrosystemtechnik biotechnologische Probleme vorteilhaft gelöst werden können. Dabei wird Bezug genommen auf aktuelle Entwicklungen, der Forschungseinrichtungen sowie der Industrie. Ferner werden Strategien zur Identifizierung neuer Anwendungen der Mikrosystemtechnik im Bereich Biotechnologie aufgezeigt. Die Themen der LVA sind:

- Spektrum der Biotechnologie
- BioMST Roadmap
- Molekulare Biotechnologie
- Wissenschaftliche Grundlagen
- Instrumentierung & Automatisierung
- Mikrobiologische Methoden
- Molekularbiologische Methoden
- Funktionsanalytik
- Gastvortrag aus der Industrie

### Inhalte Praktikum / Content of the laboratory

Das Laboratory ist als 4 tägiger Block ausgelegt. 4 Wochen vor dem Laboratory bekommt jeder Teilnehmer/in ein Thema zugeordnet, über das er/sie ein 15 minütiges Referat am ersten Tag hält ums so zum einen zu zeigen, dass auch ein biochemischer Stoff aufgearbeitet werden kann und um zugleich den anderen Kursteilnehmern/innen den Stoff aus eigener Sicht nahe zu bringen. Zu den einzelnen Versuchen sind Protokolle zu schreiben.

Vor Beginn der Versuche wird eine Sicherheitsbelehrung durchgeführt um überhaupt im Biolabor arbeiten zu dürfen. Folgende Experimente werden durchgeführt:

- Zellkulturtechniken werden erlernt, um einerseits steril arbeiten zu können und andererseits etwas Erfahrung im Umgang und der Aufzucht von Bakterien und Zellen zu erhalten. Um zu wissen wie viele Zellen vorhanden sind, werden verschiedene Zellzählungsmethoden angewendet.
• Der quantitative Nachweis von Genen wird mittels der Polymerase Kettenreaktion (PCR) durchgeführt. Hier wird eine vorgegebene DNA verarbeitet und nachgewiesen. Hierbei wird der Umgang mit DNA und das Risiko von Kontaminationen erlernt.

• Eine weitere Standardtechnik ist der Immunoassay. Hierbei wird ein Protein, welches sich aus einem entsprechenden Gen ableitet, quantitativ nachgewiesen. Es wird sowohl die klassische Methode in der Mikrotiterplatte als auch in einem zentrifugalen System durchgeführt. Hierbei soll insbesondere in der Handhabung und im Nachweis der Unterschied zwischen DNA und Protein erlernt werden.

• Als letzte Technik wird die Elektrophorese durchgeführt. Sie dient sowohl zum Nachweis von DNA als auch Proteinen. Hierbei soll der Umgang mit Gelen und wie man die erhaltenen Daten ausliest erlernt werden.

Fragen, Anregungen und Änderungswünsche sind jederzeit willkommen, da wir versuchen das Laboratory so zu gestalten, dass innerhalb kurzer Zeit ein maximales Verständnis für diese recht komplexen Techniken der Biologen erreicht werden kann.

Die Praktikumsnote setzt sich zusammen aus einem Kurzreferat zu einem Experimentalthema des Praktikums sowie der Erstellung eines Praktikumsberichtes.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Begleitend zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
## Modul / Module

### BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 2 – Biotechnological Tasks for Microsystems Technology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5317</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target

Die Studierenden gewinnen grundlegende Kenntnisse in den biotechnologischen Teilbereichen Bioverfahrenstechnik und in-vitro Diagnostik. Die Kenntnisse im Teilbereich Bioverfahrenstechnik umfassen den Aufbau und Betrieb von Bioreaktoren, up-stream und down-stream Prozesse sowie die Messtechnik an Bioreaktoren. Die Studierenden lernen das Anwendungspotential der Mikrosystemtechnik im Bereich der Bioverfahrenstechnik zu analysieren und zu beurteilen. Im Teilbereich der in-vitro Diagnostik werden Kenntnisse...

**Inhalte Vorlesung / Content of the lecture**

Anhand ausgewählter Beispiele wird gezeigt, wie durch den Einsatz der Mikrosystemtechnik biotechnologische Probleme vorteilhaft gelöst werden können. Dabei wird Bezug genommen auf aktuelle Entwicklungen germaner und internationaler Forschungseinrichtungen sowie der Industrie. Ferner werden Strategien zur Identifizierung neuer Anwendungen der Mikrosystemtechnik im Bereich Biotechnologie aufgezeigt. Die Themen der LVA sind:

- Bioverfahrenstechnik
- Bereiche und Aufgaben
- Bioverfahrensentwicklung
- UP-Stream Prozesse & Stoffumwandlung
- Down-Stream Prozesse Diagnostik
- Diagnostik
- Mikroorganismen in Lebensmitteln
- Bakterien & Viren als Krankheitserreger
- Klassisch Mikrobiologische Diagnostik
- Immun- und Nukleinsäurebasierte Diagnostik von Erregern
- Automatisierung, Miniaturisierung und Integration
- Systementwicklung, Validierung und QM

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begleitend zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.</td>
</tr>
</tbody>
</table>
Modul handbuch M.Sc. Mikrosystemtechnik – Bionische Sensoren / Bionic Sensors

Bionische Sensoren / Bionic Sensors

Nummer: Number
11LE50MO-5701

Modulverantwortlicher: Responsible person
Prof. Dr. G. Urban

Einrichtung: Organisational unit
Chair for Sensors

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
1 Lecture

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(14 Hours Full-time attendance course of study + 76 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target
The aim of this module is a basic understanding of electrical, electrochemical and optical chemo- and biosensor principles as well as the basic knowledge of biological sensors. Principles of bioinspired system and the background of bionic learning from nature to realize microtechnological systems will be discussed. Basics of electrical charge transfer and information processes in biological systems will be presented.

Inhalte Vorlesung / Content of the lecture
The lecture bionic sensors deal with learning from nature to realize technical chemo- and biosensors. Topics are:
- Biological sensors/receptors
- Charge transfer and information processes in biology
- Chemosensor, introduction
- Basics of electrochemistry
- Electrochemical potentiometric sensors
- Electrochemical amperometric sensors
- Gas sensors
- Biosensors

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Bionische Sensoren - Laboratory / Bionic Sensors - Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5702</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Kenntnisse der Inhalte in den Modulen Sensors, Bionic Sensors, BioMEMS</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

Students should gain hands on experience with several types of sensors the theory of which has been presented in the lectures “Sensors and Actuators” as well as “Sensorik und Aktorik”, and explained deeper in “Bionic Sensors” and “BioMEMS”.
Inhalte Praktikum / Content of the laboratory

Five experiments will be offered with selected types of sensors described in the lectures mentioned above. Students will work with the sensors, calibrate them, build up experiments and perform detection and measurements with the sensors under supervision of tutors.

Zu erbringende Prüfungsleistung / Examination result

Each student will have to write at least one report about one of the experiments she/he participated; during each experiment a written test and continuous discussions will take place; practical skills of the students in accordance with the basic theory will be observed and graded.

Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Biophysik der Zelle / Biophysics of the cell**

**Nummer:** Number 11LE50MO-5305

**Modulverantwortlicher:** Responsible person Prof. Dr. A. Rohrbach  
**Einrichtung:** Organisational unit Chair for Bio- and Nano-Photonics

**Modultyp:** Module Type Elective Module  
**Moduldauer:** Module duration 1 term

**Zugehörige Lehrveranstaltungen:** Connected events Lecture and exercises  
**Sprache:** Language German

**Empfohlenes Fachsemester:** Recommended term of study 3  
**ECTS-Punkte:** ECTS-points 6

**SWS:** Semester week hours 3 Lecture + 2 Übung  
**Angebotsfrequenz:** Regular cycle Only in the winter term

**Arbeitsaufwand:** Workload 180 hours (80 Hours Full-time attendance course of study + 100 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering  
  - Personal Profile
- Master of Science in Informatik  
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik  
  - Life sciences: Biomedical engineering  
  - Life sciences: Lab-on-a-chip  
  - Personal Profile
- Master of Science in Microsystems Engineering  
  - Life sciences: Biomedical engineering  
  - Life sciences: Lab-on-a-chip  
  - Personal Profile

**Lernziele / Learning target**

This module gives a survey through modern cell biophysics, addresses state of the art scientific questions and presents modern investigation methods. This comprises classical but also novel physical methods and theories, which pushed the field of biophysics together with newest measurement technology. The applied physical methods do not only inspire biology and medicine, but also the physics of complex systems, which achieves an unequalled level of self-organisation and complexity inside living cells. This lecture is designed for physicists and engineers and provides a colorful mixture of physics, biology, chemistry, mathematics, and engineering that is illustrated with numerous pictures and
animations.

**Inhalte Vorlesung / Content of the lecture**

- Structure of the cell or the receipe for cell-biophysical science
- Diffusion and Fluctuation
- Sensing and Acting measurement principles
- Biological relevant forces
- Biophysics of proteins
- Polymerphysics
- Visco-elasticity and micro rheology
- Dynamics of the cytoskeleton
- Molecular motors
- Membranephysics

**Inhalte Übung / Content of the exercises**

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur** / **Literature**

- Joe Howard: Mechanics of Motor Proteins and the Cytoskeleton.

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
CMOS-Integrierte Mikrosysteme / CMOS-Integrated Microsystems

Nummer: 11LE50MO-5716

Modulverantwortlicher: Prof. Dr. O. Paul

Einrichtung: Chair for Microsystems Materials

Modultyp: Elective Module

Modulverantwortlicher: Prof. Dr. O. Paul

Modulverantwortliche: Chair for Microsystems Materials

Dauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlenes Fachsemester: 2

ECTS-Punkte: 6

SWS: 2 lecture + 2 exercises

Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 180 hours

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - MEMS Processing
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

The most successful microsystems to date have been based on silicon. Companies such as Bosch, Analog Devices, Texas Instruments, Sensirion, and other small and medium enterprises have built their success on this wise technological choice. The lecture deals with microsystems compatible with silicon foundry services and commercial silicon technologies, in particular CMOS technologies. It will offer a healthy mix of technology, physical sensor principles and operating techniques, and will be enriched with examples that made it into the market and others that have remained scientific visions. In tune with the progress of the
lecture material, home-work will be assigned, with the presentation and discussion of solutions by students during the course hours.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Introduction</td>
</tr>
<tr>
<td>- Basic technologies</td>
</tr>
<tr>
<td>- Magnetic sensors</td>
</tr>
<tr>
<td>- Radiation sensors</td>
</tr>
<tr>
<td>- Stress sensors</td>
</tr>
<tr>
<td>- Inertial sensors</td>
</tr>
<tr>
<td>- Thermal sensors</td>
</tr>
<tr>
<td>- Chemical sensors</td>
</tr>
<tr>
<td>- Material parameters</td>
</tr>
<tr>
<td>- System integration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
## Modul / Module

**Computerunterstützte und mechanische Konstruktion / Computer-Aided and mechanic Design**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5502-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Design of Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study
- 3
- 3 ECTS-Punkte: ECTS-points

### SWS: Semester week hours
- 1 Lecture + 1 Übung
- Angebotsfrequenz: Regular cycle
- Only in the winter term

### Arbeitsaufwand: Workload
- 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile

## Lernziele / Learning target

- Kenntnisse der Vorgehensweise vom Konstruieren am PC
- Praktische Erfahrung mit CAD
- Berechnung und Auslegung einfacher mechanischer Bauelemente
- Verifikation der Auslegung durch mechanische Simulation im CAD System
- CAD Konstruktion eines komplexen Systems

## Inhalte Vorlesung / Content of the lecture

Es werden die Grundfunktionen, sowie der interne Aufbau von CAD erläutert. Zum besseren...

Zu erbringende Prüfungsleistung / Examination result
Written or oral examination

Benotung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
Dubbel: Taschenbuch für den Maschinenbau, K.-H. Grote, J. Feldhusen. 2011
Kabus: Mechanik und Festigkeitslehre, K. Kabus, 2013
DNA Analytik / DNA Analysis

<table>
<thead>
<tr>
<th>Modul / Module</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA Analytik / DNA Analysis</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer / Number</th>
<th>11LE50MO-5404</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Modulverantwortlicher / Responsible person</th>
<th>Prof. Dr. J. Rühe</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Einrichtung / Organisational unit</th>
<th>Chair for the Chemistry and Physics of Interfaces</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Modultyp / Module Type</th>
<th>Elective Module</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Moduldauer / Module duration</th>
<th>1 term</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen / Connected events</th>
<th>Lecture</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sprache / Language</th>
<th>English</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester / Recommended term of study</th>
<th>2</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ECTS-Punkte / ECTS-points</th>
<th>3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SWS / Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Angebotsfrequenz / Regular cycle</th>
<th>Only in the summer term</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand / Workload</th>
<th>90 hours</th>
</tr>
</thead>
</table>

(28 Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

<table>
<thead>
<tr>
<th>Elective Module for students of the study program</th>
</tr>
</thead>
</table>

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target

The key principles of DNA analysis are taught using standard and high tech applications to demonstrate the underlying mechanisms of DNA analysis. Starting with the biochemical role of the DNA the principles of enzymatic modification and physical detection of nucleic acids are covered. PCR is used as a demo application to introduce the key features of DNA analysis. From there on the areas of sequencing and DNA microarrays are covered as well as the use of databases to gain information about DNA sequences and how to design DNA primers and probes. The technical equipment to perform PCR, gel electrophoresis, microarray production and readout is also addressed. The lecture should give the student the theoretical background to understand, plan and perform DNA analysis research.
### Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Structure and function of DNA
- Enzymes that process DNA
- DNA amplification (PCR)
- DNA detection (gel electrophoresis, ...)
- Application in forensic sciences
- DNA microarray overview

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Various materials are available on the website [http://www.cpi.uni-freiburg.de/](http://www.cpi.uni-freiburg.de/)

Modul / Module

Drahtlose Sensornetze / Wireless Sensor Networks

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Schindelhauer</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Networks and Telematics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Lectures + 1 Exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Lehramt an Gymnasien in Informatik, major subject
- Lehramt an Gymnasien in Informatik, additional major subject
- Lehramt an Gymnasien in Informatik, major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Sensors
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
  - Informationstechnik / Information Process Technologies

Lernziele / Learning target
Students know the concrete application areas and requirements for wireless sensor networks and can apply standard methods of network layers.

**Inhalte Vorlesung / Content of the lecture**

Difference between wireless sensor networks, mobile ad-hoc networks, and cellular networks, hardware architecture, software architecture in WSN, the physical layer, medium access 802.15.4 sensor Mac, routing, data centrality, information aggregation, network lifetime, energy harvesting, resilience in wireless sensor networks, localization.

**Inhalte Übung / Content of the exercises**

Modulation, Fourier transform, routing, localization, medium access, synchronization, network lifetime active participation in the exercises.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Jie Wu, Handbook on Theoretical and Algorithmic Aspects of Sensor


527
• Ad Hoc Networks and Peer-to-Peer Networks, Auerbach, 2005
## Drahtlose Sensorsysteme / Wireless Sensor Systems

<table>
<thead>
<tr>
<th><strong>Nummer: Number</strong></th>
<th>11LE50MO-5230</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher: Responsible person</strong></td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td><strong>Einrichtung: Organisational unit</strong></td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td><strong>Modultyp: Module Type</strong></td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer Module duration</strong></td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen: Connected events</strong></td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache: Language</strong></td>
<td>English</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachsemester:: Recommended term of study** | 3 |
| **ECTS-Punkte: ECTS-points** | 3 |
| **SWS: Semester week hours** | 2 lecture + 1 exercises |
| **Angebotsfrequenz: Regular cycle** | Only in the winter term |
| **Arbeitsaufwand: Workload** | 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
### Lernziele / Learning target

With the help of microelectronics many everyday objects have to be connected to realize visions like Pervasive Computing and Ambient Intelligence. Miniaturized, self-powered wireless sensor nodes - also discussed as eGrain or Smart Dust - will make an important contribution to the networking of various objects. Miniaturized sensor nodes for wireless sensor networks represent a design problem, which is characterized by a high degree of functional complexity combined with a significant realization diversity.

### Inhalte Vorlesung / Content of the lecture

In the first part of the lecture behavioral and technological degrees of freedom of a wireless sensor system are presented and discussed intensively. Based on this, special systems such as tire pressure sensors, torque sensors and wireless sensor nodes for a logistics scenario will be discussed in detail.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

### Eingebettete Regelungssysteme Projekt / Embedded Control Project

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5246</th>
<th>Gültig ab: Valid from</th>
<th>01. April 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Vorlesungen / Courses:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Systemtheorie und Regelungstechnik / Systems and Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Systemtheorie und Regelungstechnik II /Systems and Control II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Modellierung und Systemidentifikation / Modelling and System Identification</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Term week hours</th>
<th>4 Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand: Workload</th>
<th>180 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies
### Lernziele / Learning target

Students are able to construct, to model and to simulate a mechatronic system and to design a feedback controller. In particular, they learn how to perform model based controller design and to use a rapid control prototyping approach.

### Inhalte Vorlesung / Content of the lecture

Students develop a mechatronic system of their own choice, i.e. a physical system equipped with sensors, actuators, and microcontrollers, that need feedback control for regular operation. The control is realized via a „Rapid Control Prototyping“ (RCP) system. The physical system will first be modelled, and the controller will be designed, tested, and tuned with help of computer simulations, until a desired specification is met. The control algorithm will then be directly deployed to a special control hardware of the RCP system, without the need of further programming.

### Zu erbringende Prüfungsleistung / Examination result

- written report
- oral presentation at the end of the term

### Benotung / Grading

The module grade is calculated from the result of the written report.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Will be made available to participants at the start of the project.
### Elektrochemische Energieanwendungen / Electrochemical energy applications

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5119</th>
<th>Gültig seit: Valid since</th>
<th>01.04.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
<td>Einrichtung: Organisational unit</td>
<td>Chair for MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td>Moduldaauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
</tbody>
</table>

#### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lectures + 1 Exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 hours Full-time attendance course of study + 48 Hours Self-study)</td>
<td>Only in summer term</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The students have acquired an understanding of the relevance of electrochemical systems for the global energy transition. They are able to transfer basic electrochemical effects to different electrochemical systems. They understand the connections between electrochemical analysis methods and properties of the considered electrochemical systems. They are able to propose simple strategies for the improvement of electrochemical systems.
## Inhalte Vorlesung / Content of the lecture

Electrochemical systems such as fuel cells, batteries or electrolysis cells are promising approaches for the global energy transition. Based on these examplaric electrochemical systems key electrochemical effects are taught in this course. Additionally partial thematic topics of the global energy transition such as electromobility or energy storage are discussed. Limitations and novel developments of the mentioned electrochemical systems are covered. Finally all important electrochemical characterisations methods are discussed and explained.

## Inhalte Übung / Content of the exercises

Within the excercises the topics of the lecture are reviewed deeply and complementary knowledge is taught.

## Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

## Literatur / Literature

Will be provided within the lecture.
## Modul / Module

**Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5602</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitssaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

The aim of the module is to provide the in-depth theoretical foundations and the specific technical knowledge of the micro-electro-chemical processes as well as the methodology to benchmark the process with alternative technical methods.

### Inhalte Vorlesung / Content of the lecture

- Electrochemical fundamentals (Galvanic and Corrosion Cell)
- Batteries and fuel cells
- Thermodynamics
- Nernst, Butler-Vollmer, Faraday, Porbaix
- Double layer models (Helmholtz, Gouy-Chapman, Stern-Doppelschicht, Grahame, Bockris-Müller-Devanathan, Schmickler, Henderson, Trasatti-Buzzanca, Conway, Marcus-Theory)
- Electroplating, electrolyte compositions (Ni, Au, Cu, alloys), Material properties (stress, hardness, surface roughness), MST applications
- Electrochemical machining (ECM), electrolyte compositions, Technology and variants, MST applications
- Comparison and benchmark to Spark Erosion, Technology, process characteristics, MST applications, validation and results

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Bewertung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
Accompanying the lecture, lecture notes are provided and updated regularly.
## Modul / Module

### Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5719</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Sensors</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachsemester:** Recommended term of study | 3 |
| **ECTS-Punkte:** ECTS-points | 6 |
| **SWS:** Semester week hours | 2 Lecture |
| **Angebotsfrequenz:** Regular cycle | Only in the winter term |
| **Arbeitsaufwand:** Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

The students know the essential concepts and fundamental equations of electrochemical theory. The participants from different subjects link together the knowledge from physical chemistry and several engineering disciplines to get a sound understanding of the classical electrochemical methods and electrochemical impedance spectroscopy. The students can apply their knowledge and understanding of the electrochemical methods to tasks in the
field of material science, microtechnology, Microsystems and energy application.

**Inhalte Vorlesung / Content of the lecture**

- Electrochemical theory (cells, electrodes, fundamental equation and concepts)
- Instrumentation (focus on the interplay between electrochemistry and electronics/data acquisition), equipment (electrodes, cells), and electrolytes
- Classical methods (potentiometry, amperometry, CV, DPV, SWV, HDME, RDE, RRDE)
- Electrochemical impedance spectroscopy (EIS)
- Selected aspects: Material science (corrosion, hierarchical micro-/nanostructures)
- Selected aspects: Microtechnology (electrodeposition, failure mechanism)
- Selected aspects: Microsystems (electrochemical sensors and actuators)
- Selected aspects: Energy application (fuel cells, batteries, super caps)

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

**Modul / Module**

**Energiegewinnung / Energy Harvesting**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5703</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for the Design of Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Arbeitssaufwand: Workload</td>
<td>150 hours (56 hours Full-time attendance course of study + 94 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**

The students shall learn the basic principles of (micro) energy harvesting. Several energy conversion techniques, energy storage concepts and power management strategies are described in detail. By this the students shall become able to estimate the energy generation of different harvesting techniques and to work on the design of energy autonomous embedded systems. The importance of the system-level design in these systems is, in general, a central objective in this class.

**Inhalte Vorlesung / Content of the lecture**

...
- Harmonical Oscillator (with bending beams)
- Piezoelectric Energy Harvesters
- Electrodynamical Energy Harvesters
- Electrostatic Energy Harvesters
- Non-Resonant Generators
- Thermoelectric Generators & Processes
- Thermomechanical Generators
- Capacitive Storages and Accumulators
- Step-up Converters and Advanced Step-up Converter Design
- Energy Harvesting Applications

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells

Modul / Module

Nummer: Number
11LE50MO-5203

Modulverantwortlicher: Responsible person
N.N.

Einrichtung: Organisational unit
Chair for Process Technology

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
German

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

Lernziele / Learning target

The aim of the module is to provide the in-depth theoretical fundamentals and specific skills for the storage and conversion of energy using fuel cells in micro-technical systems.

Inhalte Vorlesung / Content of the lecture

- Physikalisch chemische Grundlagen Brennstoffzellen
- Aufbau und Funktion von Brennstoffzellen
## Modulhandbuch M.Sc. Mikrosystemtechnik – Energie speicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells

- Vorstellung unterschiedlicher Brennstoffzellentypen
- Physikalisch chemische Grundlagen der Wasserstoffspeicherung
- Vorstellung von Wasserstoffspeichertypen und -mechanismen
- Diskussion von Vor- und Nachteilen der Wasserstoffspeicher
- Brennstoffzellensysteme im Automobil
- PEM
- DMFC
- Miniaturisierung von Brennstoffzellen
- Mikrobrennstoffzelle
- Chipintegrierte Brennstoffzelle (I²Brenn)
- Brennstoffzellenakkumulator
- Miniaturisierung der Wasserstoffverarbeitung
- Einsatz von Brennstoffzellensystemen in der MST

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
**Modul / Module**

**Energiewende / Energy Transition**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5802</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Winter or summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - Master of Science in Embedded Systems Engineering
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Personal Profile

**Lernziele / Learning target**

Aus den Perspektiven Technik, Ökonomie und Geisteswissenschaften soll der Zusammenhang zwischen Informationstechnologien und der ökologischen Energiewende kritisch beleuchtet werden.

**Inhalte Vorlesung / Content of the lecture**

Ziel ist die Etablierung einer innovativen Lehrveranstaltung, die ein problemlösungsorientiertes Ausbildungskonzept für Studenten aus unterschiedlichen Fachbereichen anbietet. Konkret umfasst das vorgestellte Konzept drei Aspekte (1) Gastvorträge, (2) Gruppenarbeit und (3) Präsentierbares Handlungskonzept. Durch das eigenständige Erarbeiten in interdisziplinären Teams wird die Arbeitswelt praxisnah simuliert, die Begrenzungen und die Stärken der eigenen Fachdisziplin werden konkret am
Problem erfahren und durch Einbeziehung anderer Disziplinen innovativer gelöst.

Veranstaltende Professoren:
- Prof. Becker, Lehrstuhl für Rechnerarchitektur
- Prof. Gander, Philosophisches Seminar und Husserl-Archiv
- Prof. Lausen, Institut für Informatik
- Prof. Müller, Institut für Informatik und Gesellschaft (koordinierend)
- Prof. Neumann, Lehrstuhl für Wirtschaftsinformatik
- Prof. Reindl, Lehrstuhl für elektrische Mess- und Prüfverfahren
- Prof. Schneider, Lehrstuhl für Kommunikationssysteme

**Zu erbringende Prüfungsleistung / Examination result**

- written documentation
- oral examination

**Bewertung / Grading**

The final module grade is calculated 50% of the written documentation and 50% of the oral presentation.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

#### Entwurf Analog CMOS Schaltungen / Analog CMOS Circuit Design

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Y. Manoli</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fritz Huettinger Chair of Microelectronics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

#### Zwingende Voraussetzungen: Mandatory preconditions
- System theory (basics)
- Successful participation with a minimum mark of 2.7 in the exam of one of the lectures Microelectronics or Mikroelektronik.

The limited number of seats will be distributed among applying students based on a ranking of the achieved marks.

#### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
</table>

#### SWS: Semester week hours

| 2 lecture + 2 exercises | Angebotsfrequenz: Regular cycle | Only in the summer term |

#### Arbeitsaufwand: Workload

180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
Lernziele / Learning target

The module is divided in a lecture and a practical course.

Lecture

Illustrated by the examples of simple analog circuits, e.g., amplifiers or reference circuits, this lecture puts its focus on a systematic approach to the analysis of analog circuits. After a successful participation in this course, the student will thus be able to analyze even complex systems.

Another focus is put on two of the most demanding building blocks for mixed-signal circuit design: the analog-to-digital and the digital-to-analog converter. With steadily advancing digitalization, these components have to satisfy the demands for ever increasing bandwidth, resolution and optimum power efficiency. The student will be in the position to choose the right principle for an application based on the different state-of-the-art architectures as well as the major non-idealities which limit their performance.

Finally, sensor readout circuits will be considered as examples of complex electromechanical systems in which the concepts and components considered thus far are put into application. Therewith, the student will be able to break down complex systems to simpler sub-systems and thus reduce the analysis of complex systems to the analysis and interaction of their simpler sub-systems.

Practical exercise

Based on the example of a two-stage amplifier with RC compensation, this practical exercise illustrates the typical design flow of an analog integrated circuit. According to the specifications of the amplifier, all transistors will be dimensioned based on hand calculations at first. Thus, a deeper understanding of this analog circuit will be developed. Next, the circuit will be implemented and simulated on transistor level using the software Cadence Spectre whereby its functionality will be verified. This approach represents an iterative task since the transistor parameters must be varied until all specifications are met. The student will thus learn that hand calculations are an absolute must in order to gain a first insight into the circuit while they also result in a first cut of the circuit for simulations. However, the results of the hand calculations do not present the final cut of the transistor sizes; on the contrary, they may considerably deviate from them.

The last task consists in finalizing the circuit while taking real-life conditions and nonidealities into account, e.g., temperature-, process and parameter variations. The student will thus learn that a successful implementation of an integrated circuit is only possible with a deeper understanding of the circuit’s parameters and their interaction.

At the end of the term, a presentation is to be given which covers the design on transistor level. Therein, the most critical design issues for meeting the specifications are to be explained. Thus, the student will also learn to present his/her results.

Inhalte Vorlesung / Content of the lecture

Illustrated by the examples of simple analog circuits, e.g., amplifiers or reference circuits, this lecture puts its focus on a systematic approach to the analysis of analog circuits. After a successful participation in this course, the student will thus be able to analyze even complex systems.

Inhalte Übung / Content of the exercises
Based on the example of a two-stage amplifier with RC compensation, this practical exercise illustrates the typical design flow of an analog integrated circuit. According to the specifications of the amplifier, all transistors will be dimensioned based on hand calculations at first. Thus, a deeper understanding of this analog circuit will be developed. Next, the circuit will be implemented and simulated on transistor level using the software Cadence Spectre whereby its functionality will be verified. This approach represents an iterative task since the transistor parameters must be varied until all specifications are met. The student will thus learn that hand calculations are an absolute must in order to gain a first insight into the circuit while they also result in a first cut of the circuit for simulations. However, the results of the hand calculations do not present the final cut of the transistor sizes; on the contrary, they may considerably deviate from them.

The last task consists in finalizing the circuit while taking real-life conditions and nonidealities into account, e.g., temperature-, process and parameter variations. The student will thus learn that a successful implementation of an integrated circuit is only possible with a deeper understanding of the circuit’s parameters and their interaction. At the end of the term, a presentation is to be given which covers the design on transistor level. Therein, the most critical design issues for meeting the specifications are to be explained. Thus, the student will also learn to present his/her results.

- five graded reports, presentation (at the end of the term)
- The course is successfully passed if the final presentation is passed and an average grade of 70% is achieved in the five written reports.
- Once this prerequisite is fulfilled, the student is allowed to participate in the written exam on the content of both the lecture and the project.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Lecture notes
Modul / Module

Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5208</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Y. Manoli</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fritz Hüttlinger Chair for Microelectronics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Successful participation in lecture and practical exercise Analog CMOS Circuit Design (both only offered in summer term, exam to be passed at the end of the summer term).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td></td>
<td>(32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / Learning target

This practical exercise deals with the layout of the two-stage amplifier with RC compensation which was designed on transistor level in the practical exercise Analog CMOS Circuit Design. It thus represents the second major task in the chain of the design flow of an integrated circuit consisting of “Design on transistor level”, “Layout” and
“Fabrication and Verification”. Students are able to apply basic layout techniques for transistors, resistors, capacitors, and metal layers using industry standard layout and simulation software. They can employ techniques for the reduction of mismatch such as unit elements, multi-finger transistors, interdigitation, common centroid, or guard rings. At the end of the course, the students are able to compare the results of simulations on transistor and layout level so that they can extract the influence of parasitic resistors and capacitors on the overall performance of the amplifier. At the same time, they learn to optimize the layout with respect to these non-idealities.

**Inhalte Vorlesung / Content of the lecture**

- Layout of analog CMOS integrated circuits (basics)
- Introduction of the layout tool Cadence VirtuosoXL (industry standard)

**Zu erbringende Prüfungsleistung / Examination result**

Graded reports, presentation (at the end of the term)

**Benotung / Grading**

The module grade is calculated based on the graded reports and the presentation at the end of the term.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Lecture notes
## Modul / Module

**Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5801</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Materials Processing</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>Summer term in German, winter term in English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

| 2 |
| ECTS-Punkte: ECTS-points | 3 |

### SWS: Semester week hours

| 2 Seminar |
| Angebotsfrequenz: Regular cycle | Every term |

### Arbeitsaufwand: Workload

| 90 hours (28 hours Full-time attendance course of study + 58 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

### Lernziele / Learning target

After the seminar the students are:
- Informed about the importance of good scientific practice
- Able to write a laboratory diary and technical reports
- Informed about the content of a master and PhD-thesis
- Able to give a scientific presentation (15 min), an oral poster presentation, to prepare a scientific poster as well as a poster for an open day.
Inhalte Vorlesung / Content of the lecture

The following topics will be covered during the course:
- Ancient and current scientific malpractice
- Rules for safeguarding good scientific practice
- Laboratory journal, Scientific reports (from project reports to dissertation thesis)
- Scientific presentation (15 min)
- Oral poster presentation (3 minutes lecture)
- Scientific poster presentation, open day poster
- 3 and 6 page journal paper

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The final module grade is balanced from the individual marks given for the above listed items.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Etische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Egert</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomicrotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen / Interest in interdisciplinary processing of up-to-date problems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

konstruktiven und kontroversen Dialog gebracht werden.

### Inhalte Seminar / Content of the seminar

Interdisziplinäres Seminar zu ethischen und philosophischen Aspekten der Neurotechnologie.

Folgende Themenbereiche werden jeweils unter ethischen, neurowissenschaftlichen bzw. ingenieurwissenschaftlichen Gesichtspunkten bearbeitet:

4. Ethik der Neurowissenschaften als aktuelles Gebiet der Philosophie

5. Identität, Person und Persönlichkeit als Grundbegriffe der Ethik der Neurowissenschaften

6. Spezifische philosophische und ethische Aspekte folgender Anwendungsfelder:
   - Invasive und nicht-invasive Gehirn-Maschine-Schnittstellen
   - Neuroimaging- Emotionale Integration neuronaler Prothesen
   - Tiefe Hirnstimulation
   - Optogenetische Interaktion
   - Neuro-Enhancement
   - Zukunftstechnologien und deren Einsatz

### Zu erbringende Prüfungsleistung / Examination result

Mündliche Abschlussprüfung / Oral examination

### Benotung / Grading

Die Modulnote errechnet sich zu 100% aus der mündlichen Abschlussprüfung. The module grade is calculated 100% from the results of the final oral examination.

### Gewichtung der Prüfungsleistung / Weight of examination result


### Literatur / Literature

- Lecture notes
# Flight Control Laboratory

**Nummer:** 11LE50MO-5222  

<table>
<thead>
<tr>
<th>Modulverantwortlicher:</th>
<th>Prof. Dr. M. Diehl</th>
<th>Einrichtung:</th>
<th>Chair for Systems Control and Optimisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Type:</td>
<td>Elective Module</td>
<td>Moduldauer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Laboratory</td>
<td>Sprache:</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen:** The lab course includes topics as part of the HIGHWIND project (Simulation, Optimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>2 oder 3</th>
<th>ECTS-Punkte:</th>
<th>6</th>
</tr>
</thead>
</table>
| SWS:  
Semester week hours | 4 Laboratory | Angebotsfrequenz:  
Regular cycle | Each term |
| Arbeitsaufwand:  
Workload | 180 hours  
(56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
### Personal Profile

- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

### Lernziele / Learning target

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

### Inhalte Praktikum / Content of the laboratory

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles might be remote controlled airplanes with IMUs and GPS or quadrotors, and they might be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

### Zu erbringende Prüfungsleistung / Examination result

Project work:
- A working project result
- project documentation and oral presentation

### Benotung / Grading

The final module grade is determined from an average of the grades of the project documentation and the presentation.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Fortgeschrittene Aufbau- und Verbindungstechnik / Advanced Assembly and Packaging Technology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5601</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Assembly and Packaging</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Good knowledge of assembly and packaging technologies from the compulsory lecture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

It is the aim, that after this module the students will be able to understand advanced problems in the field of assembly and packaging. Furthermore it is intended that the students will have capabilities to resolve A&P-related research tasks for micro-systems. The employed methods will start with system concepts and comprise thermal, electrical and mechanical modelling and optimisation. As a basis the student will know the fundamental elements of A&P as well as the specific technologies for interconnection, assembly and
protection. Also, the students will become familiar with the materials, their processing and properties. In this way they have the abilities for own research on micro-systems.

### Inhalte Vorlesung / Content of the lecture

The contents of teaching are mainly based on actual research projects in the chair Aufbau- und Verbindungstechnik.

Organization of the lecture:
- Introduction
- Thermal management using novel materials
- Packaging of MEMS pressure sensors
- Fatigue analysis of soldered joints
- Adhesive bonding of power electronics
- Computation of packaging stress in Hall sensors
- Concepts for sensors for mechanical properties
- High-temperature packaging
- Materials modelling in A&P
- Reliability modelling in A&P

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modulhandbuch M.Sc. Mikrosystemtechnik – Fortgeschrittene Eingebettete Systeme Laboratory / Advanced Embedded Systems Laboratory**

### Modul / Module

**Fortgeschrittene Eingebettete Systeme Laboratory / Advanced Embedded Systems Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5223</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Students require basic knowledge of VHDL, good knowledge of C and should be familiar with the basic usage of Linux.</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
</table>

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Semester week hours**

| 4 Laboratory |

**Angebotsfrequenz: Regular cycle**

| Only in the summer term |

**Arbeitsaufwand: Workload**

| 180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target

The goal is to provide students with the necessary practical background for hardware software codesign.

### Inhalte Praktikum / Content of the laboratory
This course concentrates on hardware-software-co-design, such as combining FPGA-based hardware with high level operating systems running on ARM cores. Students will learn implementing basic hardware structures in VHDL and later proceed to control that hardware directly from high level applications running on the additional ARM core. Students will work either in small groups or on their own.

**Zu erbringende Prüfungsleistung / Examination result**

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

**Benotung / Grading**

The module grade will be determined from the average of the grades of each report.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5112</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystem Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in microsystems technology and semiconductor physics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o Materials
  o MEMS Processing
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Materials
  o MEMS Processing
  o Personal Profile

Lernziele / Learning target

This module provides a more detailed description of silicon technologies exceeding the modules in Microsystemtechnology I and II. The basics in silicon technologies will be accomplished by the most recent results found in literature. Whenever possible, we will organize a visit of the Micronas GmbH in Freiburg and their CMOS Fab.
## Inhalte Vorlesung / Content of the lecture

Substrate materials, oxidation, diffusion, implantation, polysilicon and epitaxy, silicides, metallisation, dielectric layers, SiGe, strained silicon, low- und high-k-dielectrics, photo lithography (immersion lithography, phase shift mask, EUV, chemical-mechanical polishing, process integration, CMOS-compatible micro mechanics

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

## Literatur / Literature

- Chang/Sze: ULSI Technology, Wiley
- Semiconductor International: monatliche Technologie-Zeitschrift
# Modul / Module

**Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5231</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics, mathematics and micro-optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

## Lernziele / Learning target

In this module we consider topics in micro-optics in greater depth than is possible in the introductory course Micro-optics, which is a prerequisite.

At the completion of the course, the successful student should possess:
the ability to understand and analyze multi-lens and thick lens systems
an understanding of the basics of numerical modeling as well as characterization
techniques for optics
the ability to understand the structure and function of some important optical
instruments
an awareness of the most important devices and effects in MOEMS, nano-optics and
tunable optics
the ability to understand and apply these concepts in microsystems applications

Inhalte Vorlesung / Content of the lecture
A variety of optical topics with relevance to microsystems engineering is considered.
Whereas advanced techniques in geometrical optics analysis, optical modeling instruments,
and interferometry apply to macro as well as micro-optical systems, the later topics,
including MOEMS and optofluidics, are of prime importance in optical microsystems and
their applications.

Table of contents:
- Advanced geometric optics
- Optics modeling
- Optical instruments
- Interferometry
- Optics characterization
- Optical multilayers
- MOEMS
- Tunable optics
- Optofluidics

Zu erbringende Prüfungsleistung / Examination result
 oral presentation

Benotung / Grading
The module grade will be determined from the grade of the presentation.

Gewichtung der Prüfungsleistung / Weight of examination result
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of
  2009: The grade of the module is triple-weighted according to the number of its
  ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of
  2011: The grade of the module is triple-weighted according to the number of its
  ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of
  2012: The grade of the module is single-weighted according to the number of its
  ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the
  module is single-weighted according to the number of its ECTS-points in the
  calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- L. Novotny & B. Hecht: Principles of Nano-optics
- W. Smith: Modern Optical Engineering
- S. Gaponenko: Introduction to Nanophotonics
# Fortgeschrittenes Praktikum für Mikrocontroller / Advanced Laboratory in Microcontroller

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5233-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge of the course and laboratory in Microcontroller. The skills are inspected by an entry test!</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (56 hours Full-time attendance course of study + 34 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

## Lernziele / Learning target

- Work with microcontroller as a central component
- Tasks targeted in the corresponding areas divide hardware, software and HID with consideration of the issues, ergonomics, noise immunity, reliability, and efficiency of the overall design.
**Inhalte Vorlesung / Content of the lecture**

On one µC board several experiments will be executed. The base is a MSP430. Use of existing libraries or creation of your own libraries for existing sensors and interfaces. Other topics are: interrupt security-related hardware, watchdog usage, interfaces, and bus systems.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Mikrocontroller-technik Am Beispiel der MSP430-Familie: Matthias Sturm
- Das MSP430 Mikrocontroller Buch: Marian Walter, Stefan Tappertzhofen
- Halbleiter-Schaltungstechnik: Tietze, Schenk; Gamm
Modulhandbuch M.Sc. Mikrosystemtechnik – Gassensorik / Gas Sensors

Modul / Module

Gassensorik / Gas Sensors

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5704</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Thin-film Gas Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study

| 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | only in the winter term |

Arbeitsaufwand: Workload

| 90 hours |
| (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target


Inhalte Vorlesung / Content of the lecture

In der Vorlesung werden Gassensoren, die auf unterschiedlichsten, chemischen und physikalischen Prinzipien basieren, vorgestellt und deren Funktionsweise, Herstellung und Anwendung vermittelt. Gassensoren decken Massenmärkte mit sehr großen Stückzahlen
ebenso ab, wie applikationsspezifische Sonderlösungen. Folgende wichtige Grundlagen für die Gassensorik werden diskutiert:

- Wechselwirkung Gas-Halbleiter, Adsorption, Elektrische Auswirkungen von adsorbierten Gasen
- Wärmeleitung u.-kapazität, Paramagnetismus von Gasen
- Schwingungs- und Rotationsspektren im IR, Druck- und Dopplerverbreiterung, Linienformen
- Interferometer, Schwarzkörperstrahlung, Elektrochemie

Folgende Bauelemente und Messsysteme werden vorgestellt:

- Metalloxidgassensoren, Lambdasonde, Gassensitive Feldeffekttransistoren
- Wärmeleitfähigkeitssensoren, Pelistoren
- Paramagnetischer Sauerstoffsensor
- Optische Systeme (Laserspektrometer, Filterphotometer, Photoakustik, Wellenleiter), Fourier Transformations Infrarot Spektrometer
- Elektrochemische Sensoren, Elektronische Nasen

---

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

---

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

---

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

---

**Literatur / Literature**

Begleitend zur Vorlesung wird ein Folien-Skriptum zur Verfügung gestellt.
# Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5407</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for the Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only in the summer term</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Arbeitsaufwand: Workload

90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

Biochip technologies play a key role in the miniaturization and parallelization of bioanalytical techniques. They combine microbiological methods with microsystems engineering. The students will understand the requirements for the integration of modern bioanalytical methods in miniaturized devices. Special emphasis will be given to bioanalytical surfaces and surface architectures and the students will learn how to apply such concepts to chip-based bioanalytical assays.
### Inhalte Vorlesung / Content of the lecture

- Interaction of surfaces with biological environments
- Design criteria for bioanalytical surfaces and interfaces
- Procedures and techniques for biochip fabrication
- Nucleic acid based biochips
- Protein biochip technologies
- Complex biochip applications

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Reading material will be provided through the ILIAS system. An ILIAS page will be generated prior to the start of the course and communicated to the students.
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Objective of the module is to impart knowledge of the medical and biological as well as the physicochemical and technical fundamentals during electrical stimulation of nerve and muscle that are mandatory for any engineer to understand the biological processes and to design and develop technical aids and processes in the field of neural prostheses and neuromodulation.

The module teaches the students the theoretical background with respect to effects, hazards and damaging mechanisms of electrical stimulation in the peripheral and central nervous system as well as the electrochemical processes that have to be taken into account in neuro-technical interfaces.
### Inhalte Vorlesung / Content of the lecture

The lecture introduces biological-medical as well as physico-technical aspects during electrical stimulation of nerves and muscles. The following topics will be covered:

- Overview of the history of electrical stimulation
- Anatomy and physiology of nerves and muscles
- Description of electrical excitation of nerve cells
- Electrical fields and electrochemical processes at electrodes
- Methods of selective nerve stimulation
- Effects of chronic electrical stimulation of nerve and muscle
- Limits of safe electrical stimulation
- System theory and control aspects in neural prosthetics
- Simulation of nerve excitation
- Design of stimulators for electrical stimulation
- Characteristic parameters for different applications in electrical stimulation.

The learning targets and objectives will be summarized at the end of each lecture and a comprehensive summary will take place at the end of the course to repeat the most important objectives and facilitate preparation of the oral examinations.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Actual copies of the slides will be delivered accompanying to the lectures.

**Literature:**

- Horch, K.W., Dhillon, G.S. (Hrsg.): Neuroprosthetics – Theory and Practice. (Series on Bioengineering & Biomedical Engineering – Vol. 2)
- River Edge: World Scientific Computing, 2004
Modulhandbuch M.Sc. Mikrosystemtechnik – Halbleitertechnologie / Semiconductor Technology and Devices

Modul / Module

Halbleitertechnologie / Semiconductor Technology and Devices

Nummer: Number 11LE50MO-5108

Modulverantwortlicher: Responsible person Prof. Dr. M. Zacharias
Einrichtung: Organisational unit Chair for Nanotechnology

Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture
Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study 3
ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Lecture
Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (32 Hours Full-time attendance course of study + 58 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The module is specifically designed for the international master not familiar with Clean Room processes. It is a lecture which gives the basic knowledge in equipments and processes used in a Si Clean Room. In addition, the lesson will give an overview and some basic physics about typical devices like pn- junctions, solar cells, and photodetectors.

Inhalte Vorlesung / Content of the lecture

Mandatory knowledge for Si technology will be provided including wafer processing, wet and dry etching, CVD growth processes, doping, metallization, CMOS process, and others.
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5503</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair for Assembly and Packaging</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaur:</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
Knowledge in Assembly and Packaging Technology or Aufbau- und Verbindungstechnik

**Empfohlenes Fachsemester:: Recommended term of study**
3

**ECTS-Punkte: ECTS-points**
5

**SWS:**
4 Laboratory

**Angebotsfrequenz:**
Regular cycle

Only in the winter term

**Arbeitsaufwand:**
150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile

**Lernziele / Learning target**

It is the aim, that after this module, the student will know the fundamental physical problems in electronic hardware based on own numerical investigations. The student will have elementary capabilities to solve praxis-relevant design problems in assembly and packaging of MEMS using a professional finite-element-system. He/she will know how experiments can be replaced by simulation and what the necessary input data are. He/she will be able to
work with the Finite-Element-Code and to modify complex existing models. Furthermore it is expected that the student will have improved capabilities in the analysis of industrial problems and on reporting of the corresponding results.

### Zu erbringende Prüfungsleistung / Examination result

Graded protocols and a written or oral exam related to the protocols

### Benotung / Grading

The module grade is determined from an average of the grades of the individual reports.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.


**Modul / Module**

**Innovationsmanagement - der Unterschied zwischen Spotify und Aldi / Innovation Management - how Spotify differs from Aldi**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5805</th>
<th>Gültig seid: Valid since</th>
<th>01.10.2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td></td>
<td>Einrichtung: Organisational unit</td>
<td>Faculty of Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Wahlmodul</td>
<td>Moduldauer Module duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended requirements**

<table>
<thead>
<tr>
<th>Fachsemester: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Seminar</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Nur im Wintersemester</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 Stunden (48 Stunden Präsenzstudium + 42 Stunden Selbststudium)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Wahlmodul für Studierende des Studiengangs
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Fachfremder Wahlbereich
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

**Lernziele / Learning target**


Inhalte Seminar / Content of the seminar

- EINSTIEG – unfreazing der Teilnehmer (Wie innovativ bist Du?)
- VALUE PROPOSITION DESIGN - Muster der Wertschöpfung begreifen, Erfahrung und Kenntnisse des Teams nutzen und keine Zeit mit Ideen verschwenden, die nicht funktionieren.
- INNOVATIONS-KULTUR - Es hängt von der „Kultur“ ab, ob agile Methoden funktionieren: Feedback geben und annehmen, growth mindset, Neugier und Offenheit, lebenslanges Lernen und sich immer wieder in Frage stellen, eigene Filter und eigenen Stil kennen sowie den von anderen, effektives Kommunizieren, Teamwork etc..

Zu erbringende Prüfungsleistung / Examination result

Schriftliche oder mündliche Abschlussprüfung

Zu erbringende Studienleistung / Course achievement

- Regelmäßige Teilnahme
- Erstellung von Lernplakaten als Zusammenfassung der jeweiligen Seminar-Themen
- Entwicklung und Präsentation von (eigenen) Geschäftsmodellen oder Produkten

Bewertung / Grading

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen
Abschlussprüfung.

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Bachelor of Science im Fach Embedded Systems Engineering,</td>
</tr>
<tr>
<td>Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-</td>
</tr>
<tr>
<td>Punkten dreifach gewichtet in die Gesamtnote eingerechnet.</td>
</tr>
<tr>
<td>- Master of Science im Fach Embedded Systems Engineering</td>
</tr>
<tr>
<td>Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-</td>
</tr>
<tr>
<td>Punkten einfach gewichtet in die Gesamtnote eingerechnet.</td>
</tr>
<tr>
<td>- Master of Science im Fach Informatik, Prüfungsordnungsversion</td>
</tr>
<tr>
<td>2011: Die Modulnote wird nach ECTS-Punkten einfach gewichtet</td>
</tr>
<tr>
<td>in die Gesamtnote eingerechnet.</td>
</tr>
<tr>
<td>- Master of Science im Fach Microsystems Engineering, Prüfungs</td>
</tr>
<tr>
<td>ordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten</td>
</tr>
<tr>
<td>einfach gewichtet in die Gesamtnote eingerechnet.</td>
</tr>
<tr>
<td>- Master of Science im Fach Mikrosystemtechnik, Prüfungsordnu</td>
</tr>
<tr>
<td>sversion 2009: Die Modulnote wird nach ECTS-Punkten einfach</td>
</tr>
<tr>
<td>gewichtet in die Gesamtnote eingerechnet.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unternehmer denken,</td>
</tr>
<tr>
<td>entscheiden und handeln</td>
</tr>
<tr>
<td>Handbuch für Visionäre, Spielveränderer und Herausforderer</td>
</tr>
<tr>
<td>Sie Produkte und</td>
</tr>
<tr>
<td>Services, die Ihre Kunden wirklich wollen.</td>
</tr>
<tr>
<td>Mit einfachen Ideen gestalten und präsentieren</td>
</tr>
</tbody>
</table>
### Modul / Module

#### Keramiktechnologie in der Mikrotechnik / Ceramic technology in microsystems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5103</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Materials Processing</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlenes Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in &quot;Keramische Werkstoffe der Mikrotechnik&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

in der Mikrotechnik sehr wichtige Materialklasse zu wecken.

**Inhalte Praktikum / Content of the laboratory course**


**Zu erbringende Prüfungsleistung / Examination result**

graded protocols

**Benotung / Grading**

The final module grade is determined from an average of the grades of the individual reports.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Materials Processing</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering  
  - Personal Profile
- Master of Science in Informatik  
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik  
  - Materials  
  - Personal Profile
- Master of Science in Microsystems Engineering  
  - Materials  
  - Personal Profile
- Master of Science in Sustainable Systems Engineering  
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

Ziel des Moduls ist es, die technologischen und physikalischen Grundlagen der keramischen Werkstoffe und die zugehörigen Prozessierungsmethoden zu vermitteln. Mikrosystemtechnisch relevante Aspekte der keramischen Werkstoffe und ihrer
Prozessierungsmethoden sollen aufgezeigt werden.

Inhalte Vorlesung / Content of the lecture


Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Begleitend zur Vorlesung wird ein Skriptum und werden Handzettel der Lecturesfolien zur Verfügung gestellt.
**Modul / Module**

**Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5121</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S. Hiermaier</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sustainable Systems Engineering (INATECH)</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

With this module Students are able to distinguish between damage and failure as two distinct process types in materials as other thermo-mechanic behaviors. Basic differences between phenomenological and physics based modeling approaches become evident. Specifically, the multi-scale character of the process is recognized. The resulting dimensions of related resources for computations as well as the necessity for scale-bridging methodologies is learnt. Furthermore, a variety of experimental and numerical methods for characterizing and modeling the processes is investigated.

**Inhalte Vorlesung / Content of the lecture**
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Kontinuumsmechanik I / Continuum mechanics I

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4301</th>
<th>Gültig seid: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Department for Sustainable Systems Engineering (INATECH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / Learning target

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics.

Inhalte Vorlesung / Content of the lecture

- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic structure of continuum mechanics (kinematics, balance equations, constitutive relations). The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benoitung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
Modulhandbuch M.Sc. Mikrosystemtechnik – Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

Modul / Module

Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

Nummer: Number 11LE68MO-4302 Gültig seit: Valid since 01.10.2016

Modulverantwortlicher: Responsible person Einrichtung: Organisational unit

Modultyp: Module Type Elective module Moduldaurer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture Sprache: Language German or English

Empfohlenes Fachsemester:: Recommended term of study

ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 2 Lecture + 2 exercises Angebotsfrequenz: Regular cycle Only in winter term

Arbeitsaufwand: Workload 180 hours (64 hours Full-time attendance course of study + 116 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Selective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / Learning target

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Inhalte Vorlesung / Content of the lecture
- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic structure of continuum mechanics (kinematics, balance equations, constitutive relations).

The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

**Inhalte Übung / Content of the exercises**

The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
Modul / Module

Kontinuumsmechanik II / Continuum mechanics II

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4303</th>
<th>Gültig seit: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Department for Sustainable Systems Engineering (INATECH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Kontinuumsmechanik I / Continuum mechanics I</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / Learning target

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics.
<table>
<thead>
<tr>
<th><strong>Inhalte Vorlesung / Content of the lecture</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization</td>
</tr>
<tr>
<td>- Balance relations of mechanics and thermomechanics</td>
</tr>
<tr>
<td>- Principles of mechanics: principle of D'Alembert, principle of virtual displacements</td>
</tr>
<tr>
<td>- Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)</td>
</tr>
<tr>
<td>- Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Zu erbringende Prüfungsleistung / Examination result</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Benoitung / Grading</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Gewichtung der Prüfungsleistung / Weight of examination result</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- D. Helm, Einführung in die Kontinuumsmekhanik, Wiley-VCH Verlag, 2017</td>
</tr>
<tr>
<td>- P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002</td>
</tr>
</tbody>
</table>
# Modul / Module

**Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE68MO-4304</th>
<th>Gültig seid: Valid since</th>
<th>01.10.2016</th>
</tr>
</thead>
</table>

**Modulverantwortlicher: Responsible person**

**Einrichtung: Organisational unit**

- Department for Sustainable Systems Engineering (INATECH)

**Modultyp: Module Type**

- Elective module

**Moduldauer Module duration**

- 1 term

**Zugehörige Lehrveranstaltungen: Connected events**

- Lecture

**Sprache: Language**

- German or English

**Empfohlene Voraussetzungen: Recommended preconditions**

- Kontinuumsmechanik I / Continuum mechanics I
- Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

**Empfohlenes Fachsemester: Recommended term of study**

- 3

**ECTS-Punkte: ECTS-points**

- 3

**SWS: Semester week hours**

- 2 Lecture

**Angebotsfrequenz: Regular cycle**

- Only in winter term

**Arbeitsaufwand: Workload**

- 90 hours
  - (32 hours Full-time attendance course of study + 58 Hours Self-study)

---

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

## Lernziele / Learning target

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first
applications in the field of continuum mechanics.

Inhalte Vorlesung / Content of the lecture

- Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization
- Balance relations of mechanics and thermomechanics
- Principles of mechanics: principle of D'Alembert, principle of virtual displacements
- Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)
- Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

Inhalte Übung / Content of the exercises

The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- D. Helm, Einführung in die Kontinuumsmechanik, Wiley-VCH Verlag, 2017
- P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002
# Lattice Gas Methoden / Lattice Gas Methods

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5504a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Simulation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohle: Voraussetzungen: Recommended preconditions**

It is advantageous but not necessary to be familiar with the basic topics of the course "Simulation".

**Empfohlenes Fachsemester: Recommended term of study**

| 2 |

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Semester week hours**

| 2 lecture + 2 exercises |

**Angebotsfrequenz: Regular cycle**

| Only in the summer term |

**Arbeitsaufwand: Workload**

| 180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study) |

---

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

**Lernziele / Learning target**

Lecture:
The students will learn the basic theoretical descriptions of the Lattice Gas and of the Lattice Boltzmann method and their derivation from kinetic theory. The students will understand the application of these two methods to the computational tasks for the simulation of fluid
The students will learn to apply the Lattice Gas method as well as Lattice Boltzmann method to special problems in fluid dynamics. They will be assigned to implement the methods into an algorithm, estimate the computational cost for a given problem, and they will learn to elaborate the result obtained by the simulation and give a detailed interpretation of the fluid flow phenomena under investigation.

### Inhalte Vorlesung / Content of the lecture

The lectures will cover the following topics:

- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Formal classical transport theory
- The Boltzmann transport equation (BTE)
- Methods for solving the BTE
- Simple Lattice Gas Method
- Lattice Boltzmann Method

### Inhalte Übung / Content of the exercises

This exercise will accompany the topics given in the course on Advanced Topics in Simulation: Lattice Gas Methods. The exercises will focus on problems to be solved with the software tool Mathematica. The students will be assigned with a project to be solved by Mathematica. To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the
module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Sauro Succi: The lattice Boltzmann equation for fluid dynamics and beyond, Oxford University Press, 2001, Fakultätsbibliothek Ang, Wiss, Frei 91: AB/3.0/89
- Dieter A. Wolf-Gladrow, Lattice gas cellular automata and lattice Boltzmann models, Springer-Verlag, 2000
Modul / Module

Lithographie für Microsystems Engineers/ Litography for Microsystems Engineers

Nummer: Number 11LE50MO-5608

Modulverantwortlicher: Responsible person N.N.
Einrichtung: Organisational unit Chair for Process Technology

Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture
Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge of the modules
- MST Technologies and Processes
- Cleanroom Laboratory

Empfohlenes Fachsemester: Recommended term of study 2
ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Lecture Angebotsfrequenz: Regular cycle

Only in the summer term

Arbeitsaufwand: Workload 90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  o MEMS Processing
  o Personal Profile

Lernziele / Learning target

At the end of the block seminar the students should have learned the basic knowledge to perform a simple troubleshooting for photoresist processing in a cleanroom environment and should be able to choose the appropriate technique for the realization of micro- or nanostructures.

Inhalte Vorlesung / Content of the lecture

The purpose of this block course is to deepen the existing knowledge of lithography for micro structures (gained by the lecture “MST- Technologies and Processes”) and to learn the basics of alternative state-of-the-art lithography techniques such as nanoimprinting (UV-
NIL, HEL, etc.), interference lithography, contact printing. The students will be introduced to a more profound knowledge of the working principles of modern photo resists used in Microsystems Technology. The necessary equipment and tools for lithography are also covered (mask-aligner, photo mask, microscope, etc.).

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Marc Madou "Fundamentals of Microfabrication"
- Hand-Outs to the single subjects will be provided at the block seminar.
## Modul / Module

### Magnetische Mikrosysteme / Magnetic Microsystems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5206</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Wallrabe</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes</td>
</tr>
<tr>
<td>Fachsemester:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

### Lernziele / Learning target

The purpose of this module is to give an overview of the diverse microsystems having as a chief operating principle the magnetic interactions. Several features specific to magnetic microsystems will be highlighted during the lecture: generation of stable forces without power supply, levitation, remote actuation, electrical generation, high energy density. A special attention will be paid to the building blocks of magnetic microsystems: various technologies to build microcoils, processing of active magnetic materials, and integration of
Micro-magnets in magnetic microsystems. Several applications will be reviewed, among
them: magnetic resonance imaging and spectroscopy at the microscale, motors, generators,
electromagnetic microbearings to eliminate friction and wear.

**Inhalte Vorlesung / Content of the lecture**

A brief introduction/reminder of magnetism will be given at the beginning of the lecture
covering: magnetic fields and sources of magnetic fields, electromagnetic induction,
magnetism and matter.

MEMS processes specific to magnetic microsystems will be reviewed in detail:
- microcoil fabrication techniques for:
  - planar microcoils – spiral and loop coils
  - 3D microcoils – rectangular cross-section, axis parallel to the substrate
  - 3D microcoils – circular cross-section, axis perpendicular to the substrate
  - other techniques
- processing of thin magnetic layers: deposition, lamination
- integration of magnetic materials in magnetic microsystems

The third part of the lecture will be dedicated to investigate several magnetic microsystems
with specific functionalities. Among them, but not limited to:
- Magnetic resonance. Imaging (MRI) and spectroscopy (NMR)
- Basics
- MRI and NMR at the microscale. The general problem
- Design of MR micro-detectors:
  - Microcoils: planar, 3D
  - Planar microslot waveguide
  - The stripline as an NMR micro-detector
- Electromagnetic levitation. Electromagnetic microbearings
- Device: design and fabrication
- Theory: device characterization
- Electromagnetic energy harvesting
- Eddy current applications
- Proximity sensing and crack detection
- Damping (experiment)
- Scanning mirror using Lorentz force and magnetostatic force

**Zu erbringende Prüfungsleistung / Examination result**

At the beginning of the lecture the students will be presented with a list of topics in
connection with the general purpose of the lecture. Each student will have to choose one
topic and make a relevant literature review centered on that topic. This literature review will
be than presented in an oral presentation followed by a discussion.

**Benotung / Grading**

The module grade is calculated from the results of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of
  2011: The grade of the module is triple-weighted according to the number of its
  ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Lecture notes will be provided.
Modulhandbuch M.Sc. Mikrosystemtechnik – Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms

Modul / Module

Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms

Nummer: 11LE50MO-5115

Modulverantwortlicher: Prof. Dr. C. Eberl
Einrichtung: Chair for Micro- and Materials’ Mechanics

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture
Sprache: English

Empfohlenes Fachsemester: 2
ECTS-Punkte: 3

SWS: 2 Lecture
Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o Materials
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Materials
  o Personal Profile
- Master of Science in Sustainable Systems Engineering
  o Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

The goal is to learn how materials properties and their impact on functionality and performance of micro systems. You will learn about the physical mechanisms in structural and functional materials as well as damage evolution during the applications lifetime. Based on the physical understanding you can evaluate microsystem designs, improve their lifetime and performance. This allows specifying materials and systems closer to their performance limit.
### Inhalte Vorlesung / Content of the lecture

Introduction: physical mechanisms  
Fundamentals in stress and strain as well as anisotropic properties  
Fundamentals in mechanics of beams and membranes explained in examples  
Micro- and nanostructured materials in micro systems  
Small scale characterization of mechanical properties  
- Intrinsic stresses  
- Elastic and plastic behavior  
- Adhesion properties  
Physical principles and loading conditions in functional materials for actors and sensors

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- L.B. Freund and S. Suresh: „Thin Film Materials“  
## Modul / Module

**Mikroakustik / Microacoustics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5207</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester: Recommended term of study
- 3 ECTS-Punkte: ECTS-points: 3
- SWS: Semester week hours: 2 lecture + 1 exercises
- Angebotsfrequenz: Regular cycle: Only in the winter term
- Arbeitsaufwand: Workload: 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target

Students will gain an understanding of the structure, operation and applications of micro acoustic devices. You will learn the basic methods for designing, modeling, for the optimization and for the production of these components. You know the functioning of bulk acoustic wave oscillators, surface acoustic wave components, as well as membrane and Bragg reflector-based thin film components.

You will be able to design and analyze simple "Finite Impulse Response" and "Infinite..."
Impulse Response" filter. Students know the applications of micro acoustic components in wireless communications and in sensor technology.

### Inhalte Vorlesung / Content of the lecture

The Micro Acoustics deals with the generation and manipulation of high-frequency (electro-) mechanical waves which enables the realization of high-frequency filters, sensors and actuators. The generation and manipulation is carried out via planar microstructures on piezoelectric materials on which these waves are performed.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Mikroakustik - Seminar / Microacustics - Seminar

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5226</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Seminar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
</tbody>
</table>

Arbeitsaufwand: Workload

| 90 hours |
| (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

The seminar micro acoustic offers the opportunity to work independently on a topic of micro acoustic and to present the results in a final presentation. As part of this work there will be built up based knowledge in specific areas of micro acoustic, and a scientific way of working is trained as well. The independent literature review is an integral part of the seminar paper. There is a personal attention of the seminar participants, which is essentially limited to the clarification of concrete, subject-specific issues. The seminar concludes with an oral exam in the form of the final presentations,
which are followed by a brief discussion.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
### Modul / Module

**Mikrobiologische Grundlagen für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5406</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

Understanding principle molecular biology processes used in technical systems for the analysis of biomolecules. The participant will understand methods such as DNA analysis (example PCR) and protein analysis (example ELISA) and will learn how to plan for the equipment and performance of such experiments.
### Inhalte Vorlesung / Content of the lecture

- DNA Analysis (Enzymes / Methods / Equipment)
- Different PCR methods
- DNA Fingerprinting
- Protein Analysis (Enzymes / Methods / Equipment)
- Antibody based detection (ELISA)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Materials will be provided through the ILIAS system. An ILIAS page will be generated prior to the start of the course and communicated to the students.
Mikrofluidik II: Mikrofluidische Plattformen / Microfluidics II: Platforms

Nummer: Number
11LE50MO-5405

Modulverantwortlicher: Responsible person
Prof. Dr. R. Zengerle

Einrichtung: Organisational unit
Chair for MEMS Applications

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
German

Empfohlene Voraussetzungen: Recommended preconditions
Knowledge in Micro-fluidics

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target
Insgesamt soll der Student erkennen welche Potentiale, aber auch Limitierungen, die Mikrofluidik und deren Anwendung im Bereich der Lebenswissenschaften besitzt. Und dass man sich generell hier in einem noch nicht fest etablierten Feld befindet, wo es noch viele
Pioniere gibt und geben kann.

**Inhalte Vorlesung / Content of the lecture**


Kapillar getriebene µFP (1 Doppelstunde) bewegen Flüssigkeiten mittels Kapillarkräfte und sind wohl die ältesten Anwendungen in Form des allseits bekannten „Schwangerschaftstests“. Es werden der Aufbau und die Möglichkeiten zur Diagnostik dieser Systeme aufgezeigt. Zusätzlich wird erklärt, wie genau ein Immuno-Assay ablaut (ebenso ein ELISA) und welche Reagenzien im System enthalten sind. Druckgetriebene µFP (2 Doppelstunden) erlauben die Aktuation der Flüssigkeiten mittels Druckunterschiede. Zunächst werden unterschiedliche Systeme zur Herstellung dieser Druckdifferenz, sowie die Vor- und Nachteile vorgestellt. Aktuelle Anwendungen wie Partikeltrennung, Diagnostik-anwendungen (Herzfarktschnelltest, Probenaufreinigung und PCR) bis hin zur „Large Scale Fluidik Integration“ als Analogie zu Mikroelektronik werden dann detailliert besprochen. Zusätzlich wird erklärt wie man mittels PCR Genesequenzen amplifizieren und detektieren kann.

Beim Zentrifugale µFP (2 Doppelstunden) nutzt man neben der Zentrifugalkraft auch Euler-Coriolis- und Kapillarkräfte zur Prozessierung und Verschaltung von Flüssigkeiten. Eigene im Chair entwickelte und weitere Anwendungen dieser Plattform wird dann am Beispiel von Probenaufreinigung, GenoTyp / Typeisierung bis hin zu Immunoassay dargestellt. Zusätzlich wird die Aufreinigung von DNA aus einer Probe erläutert.

Elektrokinetische µFP (1 Doppelstunde) nutzen mehrere Effekte die durch elektrische Felder hervorgerufen werden. Hierunter fallen die Elektrophorese, die Elektroosmose und die Dielektrophorese. Zunächst werden jedoch die Grundlagen der Chromatographie erklärt um ein Verständnis für die Anwendungen wie Gelelektrophorese, 2D-Elektrophorese und Isoelektrische Fokussierung zu schaffen. Free scalable non-contact dispensing µFP (1 Doppelstunde) beschäftigen sich damit wie man kleinste Flüssigkeitsmengen dosieren und transferieren kann. Ein Auslegungsbeispiel ist der allseits bekannte Tintenstrahldrucker. Es werden Systeme im Detail erklärt, die hier am Chair als Dispensing Wellplate und die TopSpot technologie entwickelt wurden.

High sampling µFP (2 Doppelstunden) beschäftigen sich damit wie man einige hundert bis Millionen von Assays oder Analysen parallel durchführen kann. Hierunter fallen die Mikroarrays und die Entwicklung der Pikowellplatte aus der ursprünglichen Mikrotiterplatte bis hin zur Einzel-zell-Analyse. Zusätzlich wird erklärt wie und warum man chemische Bibliotheken herstellt und austestet.
### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Students will receive a handout that will be updated on a regular basis.
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5604</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Materials' Processing</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study | 3 | ECTS-Punkte: ECTS-points | 3 |

SWS: Semester week hours | 2 Lecture | Angebotsfrequenz: Regular cycle | Only in the winter term |

Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

Besides silicon and the established MEMS/MOEMS technology polymer materials and the related microreplication technologies are becoming more and more important for the realization and commercial success of new microcomponents and microsystems. New nanostructuring methods like 2-photon-stereolithography and others are at the threshold of leaving the laboratory status and entering market. The course will cover the large variety of polymer materials, their fundamental chemical and physical properties and the derived
microstructuring and replication possibilities. Direct and indirect micro- and nanostructuring methods like deep X-ray lithography, stereolithography, laser machining, nanoimprinting and others as well as the large family of replication methods like hot embossing and injection molding will be described in detail. Master and tooling fabrication methods like electroplating, electro discharge machining as well as mechanical and laser micromachining will be presented and discussed intensely. A large number of application examples and case studies dealing with the accessible geometries, feasibility, and process characteristics will be used for the presentation of the polymer microfabrication importance.

Contents:
- Polymers: Fundamental chemical and physical properties
- Fabrication of molding tools: Fabrication principles and characteristics
- Rapid Prototyping in microsystem technology
- Polymer replication techniques: Reaction Molding, UV-Embossing, Hot Embossing and Injection Molding: Principles, equipment, applications and case studies
- From micro to nano: Nanoimprinting, soft lithography, nanostereolithography and other new developments

written or oral examination

The module grade is calculated from the result of the final examination.

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Modul / Module

**Mikrosystemtechnik in der Medizin / Microsystems technology in Medicine**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5307</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. M. Boeker</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Faculty of Medicine</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Grundlegende physikalische Kenntnisse</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

### Lernziele / Learning target

Wichtige Anwendungen der Mikrosystemtechnik in der Medizin beschreiben können:
- Computergestützte Bildanalyse
- Patch-Clamp Verfahren
- Klinische Anwendung beim Mammakarzinom
- Cochlea-Implantat
- Sehprothesen
- Diagnostik und Therapie von Herzrhythmusstörungen
- Volumetrische Bildgebung in der Radiologie

**Inhalte Vorlesung / Content of the lecture**

Dozenten aus verschiedenen Fachbereichen der Medizin stellen wichtige und aktuelle Themen der Mikrosystemtechnik in der Medizin vor: Sehprothesen, Cochlea-Implantate, minimal invasive Gefäßtherapien, computergestützte Tumordiagnostik, klinische Anwendungen beim Brustkrebs, Diagnostik und Therapie von Herzrhythmusstörungen und Verfahren der Bildanalyse in der bildgebenden Diagnostik. Dabei stellen die Dozenten insbesondere eine Verbindung zwischen den medizinisch-biologischen Gegebenheiten im menschlichen Organismus und der technischen Herangehensweise an ein spezifisches medizinisches Problem her, ohne dass besondere medizinische Kenntnisse vorausgesetzt werden.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bnotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Modulhandbuch M.Sc. Mikrosystemtechnik – Modellbildung und Systemidentifikation / Modelling and System Identification

## Modul / Module

### Modellbildung und Systemidentifikation / Modelling and System Identification

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimisation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlene Voraussetzungen: Recommended preconditions

Knowledge of
- Mathematik I für Ingenieure und Informatiker / Mathematics I für Engineers and Computer Scientists
- Mathematik II für Ingenieure / Mathematics II für Engineers
- Differentialgleichungen / Differential Equations
- Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control

### Empfohlenes Fachsemester:: Recommended term of study

| 3 |

### ECTS-Punkte: ECTS-points

| 6 |

### SWS: Semester week hours

| 2 lecture + 2 exercises |

### Angebotsfrequenz: Regular cycle

Only in the winter term

### Arbeitsaufwand: Workload

| 180 hours (64 hours Full-time attendance course of study + 116 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- Master of Science in Embedded Systems Engineering

Elective Module for students of the study program
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Kognitive technische Systeme
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.

### Inhalte Vorlesung / Content of the lecture

Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture notes
- Lecture manuscript "System Identification" by J
Mold Flow Simulation for Replication Processes

Table:

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5605</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

The module is focusing on the theoretical concepts and algorithm of process simulation for micro replication. Design Rules for Micro- Nano replication will be formulated. Gate and runner Balancing, cavity design and the influence on crystallisation, shrinkage and warpage will be studied. Experimental results obtained under different processing conditions will be simulated by state of the art software tools.

Inhalte Vorlesung / Content of the lecture

- Design of Material for Products
• Thermoset and rubber
• Amorphous polymer
• Semi crystalline polymer
• Process and Technology
• Mould and process Control
• Injection Moulding-Micro Injection Moulding
• Extrusion
• Thermoforming
• Fundamental Model for replication
• Thermal
• Mechanical
• Viscoelastic
• Rheology
• Filling, Compression, Packing and Cooling
• The downscaling of replication
• Wall Slip
• Turbulent Flow
• Process Instabilities (Air bubbles, vacuoles)
• Shear Thinning and Heat conduction and heat transfer
• Training on Software tools for simulation
• Material Characterisation
• Mould Model-Machine Model
• Meshing

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Accompanying the lecture are the lecture notes, made available and updated regularly.
### Modulhandbuch M.Sc. Mikrosystemtechnik – Nanobiotechnologie / Nanobiotechnology

#### Nanobiotechnologie / Nanobiotechnology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5308</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ambacher</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Compound Semiconductor Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Physiologie des Menschen, R.F. Schmidt, F. Lang, G. Thews, Springer Medizin Verlag Heidelberg 2005
# Nanomaterialien / Nanomaterials

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5104</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basiswissen in Festkörperphysik</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>4</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

## Lernziele / Learning target

The aim of the module is to give an introduction into modern methods for bottom-up approaches for nanomaterials. The bottom-up growth will be discussed on selected examples. Methods of functionalizing nanomaterials and surfaces will be presented. The lecture will also include some basic knowledge on size effects and high resolution characterization methods. Overall the module gives instructions in nanoscaled growth as well as in understanding the basic material properties of such bottom-up grown nanomaterials. In addition, the module
will develop basic theoretical understanding for material effects on the nanoscale and will give a deeper understanding of state of the art nanomaterial growth as well as future developments.

### Inhalte Vorlesung / Content of the lecture

After a short introduction on basics of bottom-up growth the lecture will summarize the state of the art knowledge in nanomaterials growth. Highly relevant examples from research will be discussed in detail developing the knowledge of material growth as well as basic understanding in selected growth techniques. The bottom-up growth will be discussed on selected examples which include: carbon nanotubes, Si nanoclusters and nanocrystals, Si nanowires, ZnO nanowires, colloidal methods for II-VI nanoclusters, nanobiological systems. The lecture will also include some basic knowledge on size effects and high resolution characterization methods. At the end methods of functionalizing nanomaterials and surfaces will be taught.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in Applications: Environmental Aspects and Nanotoxicity

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5318</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The aim is to learn what nanomaterials are and where they are utilized. Especially differences to bulk materials in context of utilization and toxicity will be discussed. The students should be able after the course to contribute in public discussions about "nanotoxicity" and "nanomaterials" a scientific viewpoint and balanced opinion. Furthermore the lecture should stimulate the scientific potential as well as the awareness of risks of nanomaterials in future research efforts of the students in the framework of Bachelor, Master
and PhD theses.

**Inhalte Vorlesung / Content of the lecture**

- Introduction to nanomaterials and aspects of toxicity
- Applications of colloidal metal and semiconductor nanoparticles
- Applications of nanocarbon compounds
- Applications of other nano(composite) and nanohybrid materials
- Nanomaterial drugs and drug carrier systems
- Environmental aspect of (nano)materials
- Interaction of nanomaterials with organism; Uptake and fate of nanomaterials
- Nanotoxicity legislation aspects

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Nano – Laboratory / Nano - Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Students must have passed either the module Nanomaterials or the module Nanotechnology.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

Educational objective is a demonstration of applied nanotechnology using standard methods of semiconductor thin film technology. The students will apply nanolithographic methods, grow nanostructures via self-organization and get introduced in standard characterization methods (PL, SEM, EDX). Overall, the lab course provides insight into fundamental research on nanostructures and demonstrates how basic properties of materials change at the nanoscale.
Inhalte Praktikum / Content of the laboratory

- Fabrication of size-controlled silicon quantum dots
- Atomic layer deposition (ALD) of ZnO thin films
- Gold nanodots/lines via phase shift nanolithography
- ZnO nanowire growth via vapor-solid (VS) method
- SnO2 nanowire growth via ionic-liquid assisted vapor-liquid-solid method (VLS)
- Photoluminescence spectroscopy of Si and ZnO nanostructures
- Imaging and elemental analysis of nanostructures using scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDX)

Zu erbringende Prüfungsleistung / Examination result

2. Multiple choice test at the beginning, which has to be passed to continue with the lab course.
3. Presentation and oral exam at the end of the lab course.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Nanotechnologie / Nanotechnology

<table>
<thead>
<tr>
<th>Number: Nummer</th>
<th>11LE50MO-5106</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Nanotechnology</td>
</tr>
<tr>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basiswissen in Festkörperphysik</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended term of study</th>
<th>2 oder 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Workload</td>
<td>90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

The aim of the module is to give an introduction into modern methods for the growth of nanomaterials as well as to learn the principles of high resolution investigation (SEM, TEM, HRTEM, STM, AFM, and SNOM). Methods of nanodeposition such as atomic layer deposition (ALD), methods of low dimensional growth (such as molecular beam epitaxy) and methods of self organization are summarized and presented based on selected examples.
The today status of nanolithography (porous nano templates, nanosphere lithography, and interference lithography) will be discussed in details. The module gives instructions in basic knowledge of nanoscaled growth as well as in understanding the basics in high resolution structural investigation techniques of nanostructures. In addition, the module will develop a basic theoretical understanding for size effects on the nanoscale and will give a deeper understanding of state of the art nanotechnology as well as future developments.

Inhalte Vorlesung / Content of the lecture

After a short introduction in nanotechnology the lecture will start with discussing different size effects from point of physics as well as applications. After that the methods and equipments used for defined growth of nanostructures and nanolayers will be presented and advantages and disadvantages of the various methods will be demonstrated on selected examples. Quantum structures based on III-V semiconductors representing the modern status of optoelectronic LED and laser devices, silicon nanocrystal based structures, nanotubes (carbon, spinel), and photonics crystals are used as example for applications of nanostructures in optics and electronics. In relation to our own research methods for spatially arranged nanowire growth are discussed. The lectures will also include knowledge on the development of nanodevices (memories, nanosensors, nanolaser) and the basic structural, optical and electronic investigation.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Neurophysiologie – Laboratory / Neurophysiology - Laboratory

Nummer:
Number
11LE50MO-5316

Modulverantwortlicher:
Responsible person
Prof. Dr. U. Hofmann

Einrichtung:
Organisational unit
Faculty of Medicine

Modultyp:
Module Type
Elective Module

Moduldauer:
Module duration
1 term

Zugehörige Lehrveranstaltungen:
Connected events
Laboratory

Sprache:
Language
English

Empfohlenes Voraussetzungen:
Recommended preconditions
Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing technologies" or participation in the seminar „Neuroprosthetics“ in the last winter semester.

Empfohlenes Fachsemester:
Recommended term of study
2

ECTS-Punkte:
ECTS-points
3

SWS:
Semester week hours
3 Laboratory

Angebotsfrequenz:
Regular cycle
Only in the summer term

Arbeitsaufwand:
Workload
90 hours
(42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Participants will gain first hand experiences into neuroscientific and electrophysiologically verifiable paradigms to natural signal processing in the rat brain in vivo. Participants will get in depth insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat's learning and orientation system will be introduced in depth as well. Signal processing methods will be presented and for later use in exercises substantiated. Participants will learn a respectful and honorable handling of living beings, even if they are „only“ lab rats. Students will gain first hand experience with multisite electrophysiological recordings from anesthetized and freely moving animals. Signals acquired during these day long
experiments will be analyzed according to state of the art and results will be presented as reports and talks.

**Inhalte Vorlesung / Content of the lecture**

Students will in three neurophysiological paradigms (two acute, one freely behaving) under experienced supervision participate. Students will get in depth and first hand insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat’s learning and orientation system will be introduced as well. Signal processing methods will be presented and for later use in exercises substantiated. They will gain hands on experience with in vivo animal electrophysiology with micro devices and collect data for subsequent home based analysis. Their analysis results will be presented as final teaching experience.

**Zu erbringende Prüfungsleistung / Examination result**

Written reports and presentation

**Benotung / Grading**

The final module grade is calculated from the tests during the experiments (1/3) plus the grade from the oral presentation (2/3).

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- diverse journal papers like:
# Neuroprosthetics

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5318</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. U. Hofmann</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Faculty of Medicine</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
<tr>
<td><strong>Empfohlene Voraussetzungen:</strong> Recommended preconditions</td>
<td>High school education in mathematics and natural sciences</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachsemester:** Recommended term of study | 3 |
| **ECTS-Punkte:** ECTS-points | 3 |
| **SWS:** Semester week hours | 3 Seminar |
| **Angebotsfrequenz:** Regular cycle | Only in the winter term |
| **Arbeitsaufwand:** Workload | 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

## Lernziele / Learning target

Neuroprosthetics is an emergent field of biomedical engineering aiming at developing devices to replace or augment non-functional sensory or motor pathways of humans resulting from disease or trauma.

The participating student will be instructed on the basic neuromedical concepts, and the targeted medical deficits, both needed to evaluate current clinical neuroprostheses and critically assess devices under development.

The student will gain well-funded knowledge on clinical applications and technologies and
will have to face the more biological and ethical aspects of these devices and treatment options as well.
The module aims at active involvement by independent webbased information acquisition, oral presentation of findings and internet based reporting.

**Inhalte Vorlesung / Content of the lecture**

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson’s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

**Zu erbringende Prüfungsleistung / Examination result**

- 40 % on the presentation
- 40% on the topic website
- 20 % active involvement

**Bewertung / Grading**

The final module grade is calculated 40 % on the presentation, 40% on the topic website and 20 % active involvement.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE</td>
</tr>
</tbody>
</table>
Modul / Module

Neurowissenschaften für Ingenieure / Neuroscience for Engineers

Nummer: Number
11LE50MO-5319

Modulverantwortlicher: Responsible person
Prof. Dr. U. Egert

Einrichtung: Organisational unit
Chair for Biomicrotechnology

Modultyp: Module Type
Elective Module

Modulduer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 lecture + 1 exercises

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

Lernziele / Learning target

The aim of this module is to convey an understanding of fundamental neuroscientific concepts, methods, processes and structures that define or influence the function of technical components in biomedical applications.

Inhalte Vorlesung / Content of the lecture

The lecture series conveys the foundations of various neuroscientific processes, structures and measuring techniques.
We emphasize processes that
- influence the generation and properties of signals measurable with neuronal systems,
- influence the usability of MST components, such as sensors and implants,
- are relevant for typical fields of application of MST components, e.g. implantable sensors, prostheses, neurotechnology, etc..

In the course of the lectures we will present an overview of central neuroscientific concepts, tools and applications.

Main topics are:
- Structure of the nervous systems
- Biophysics of electrical potentials
- Neuronal networks and their signals
- Sensory systems
- Foundations of learning and memory
- Interaction with neuronal networks

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Reading material will be presented during the lecture.
## Modul / Module

Netzfreie Methoden in technischen Anwendungen / Particle Methods in Engineering

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5122</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S. Hiermaier</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sustainable Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (42 Hours Full-time attendance course of study + 138 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Mikrosystemtechnik
    - Materials
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Materials
    - Personal Profile
  - Master of Science in Sustainable Systems Engineering
    - Nachhaltige Materialien / Sustainable Materials

### Lernziele / Learning target

Meshfree methods are recognized as alternative spatial discretization technique. Specific advantages in describing large deformation type processes like automotive crash, bird strike or meteoroid impact are seen as well as the numerical problems in terms of stability and convergence. Students learn the differences between meshfree methods and standard methodologies like finite element, finite differences or finite volume approaches. Application show the specific potential of meshfree methods as well as their limitations.

### Inhalte Vorlesung / Content of the lecture

To be announced.
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5225</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). The course is self contained and can be followed by all students with sufficient background in mathematical systems and control theory. It is recommended not only to master students of engineering, but also to students of computer science, mathematics, and physics. An optimization course (e.g. „Applied Convex and Nonlinear Optimization” or „Optimal Control and Estimation”) is an advantage, but not necessary.

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th></th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
### Lernziele / Learning target

Aim of this module is to give both theoretical background and hands-on practical knowledge in theory and numerics for nonlinear model predictive control (NMPC). In particular, participants shall become able to formulate and to numerically solve NMPC problems with the help of modern computing tools.

### Inhalte Vorlesung / Content of the lecture

The course covers all topics relevant for the theory and numerical solution of nonlinear model predictive control (NMPC) problems. It starts by recalling concepts from systems theory in continuous and discrete time as well as concepts from nonlinear optimization with equalities and inequalities, and the computation of derivatives. The major focus of the course is on the stability theory of NMPC and what impact it can have in control engineering practice. A second focus is on the numerical solution of nonlinear model predictive control and moving horizon estimation problems.

### Inhalte Übung / Content of the exercises

All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python and CasADi (both open-source), and participants are recommended to bring a laptop. At the end of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards at end of the course, after the written exam.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Numerische Optimale Steuerung mit Differentiell-Algebraischen Gleichungen / Numerical Optimal Control with Differential Algebraic Equations**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5245</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaurer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Mathematics such as Calculus, Linear Algebra, basic programming skills, and some familiarity with optimization and control.

Previous spring/summer schools on "numerical optimal control" or one or both of the lectures "optimal control and estimation" or "numerical optimization".

**Empfohlenes Fachsemester: Recommended term of study**

| 3 |
| 3 |

**ECTS-Punkte: ECTS-points**

<table>
<thead>
<tr>
<th>2 Lecture + 2 Exercises</th>
</tr>
</thead>
</table>

**Angebotsfrequenz: Regular cycle**

| Only in winter term |

**Arbeitsaufwand: Workload**

| 90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- **Master of Science in Embedded Systems Engineering**
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- **Master of Science in Informatik**
  - Fachfremder Wahlbereich Mikrosystemtechnik
- **Master of Science in Mikrosystemtechnik**
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- **Master of Science in Microsystems Engineering**
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
**Lernziele / Learning target**

Students understand methods for solution of optimal control problems with differential-algebraic equations and can independently apply the acquired knowledge.

**Inhalte Vorlesung / Content of the lecture**

The course is divided into two parts:

3. Foundations for Numerical Optimal Control:
   - Python and CasADi, Optimal control with Ordinary Differential Equations, Direct Transcription and Shooting Methods
4. Optimal Control with Differential Algebraic Equations:
   - Formulation, Invariants, Index Reduction, Mechanical and Aerospace Applications

**Inhalte Übung / Content of the exercises**

Theoretical and computer exercises accompany the lecture to deepen the understanding. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the
<table>
<thead>
<tr>
<th>Calculation of the overall grade.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master of Science in Microsystems Engineering. Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
## Modul / Module

### Numerische Optimierung / Numerical Optimization

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5243</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester:: Recommended term of study

| 3 |

### ECTS-Punkte: ECTS-points

| 6 |

### SWS: Semester week hours

| 4 lecture + 2 exercises |

### Angebotsfrequenz: Regular cycle

| Only in the winter term |

### Arbeitsaufwand: Workload

| 180 hours (96 hours Full-time attendance course of study + 84 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Informatik
    - Kognitive Technische Systeme
    - Fachfremdes Wahlmodul Mikrosystemtechnik
  - Master of Science in Embedded Systems Engineering
    - Circuits and Systems
    - Robotics and Computer Vision
    - Personal Profile
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Sustainable Systems Engineering
    - Informationstechnik / Information Processing Technology
### Lernziele / Learning target

Students understand important optimization methods used in practice for solution of convex and nonlinear programming problems and can independently apply the acquired knowledge.

### Inhalte Vorlesung / Content of the lecture

The course is divided into four major parts:

1. **Fundamental Concepts of Optimization**: Definitions, Types, Convexity, Duality
2. **Unconstrained Optimization and Newton Type Algorithms**: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
3. **Equality Constrained Optimization Algorithms**: Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods
4. **Inequality Constrained Optimization Algorithms**: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

### Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. Successful participation/solution of at least 50% of the weekly exercise sheets.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004
# Modul / Module

### Numerische Optimierung Projekt / Numerical Optimization Project

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5244</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Numerical Optimization Lecture (participation in the project is only possible for participants of the lecture)</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester: Recommended term of study

| 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 1 project |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (16 hours Full-time attendance course of study + 74 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  - Kognitive Technische Systeme
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
<table>
<thead>
<tr>
<th><strong>Lernziele / Learning target</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Students can independently program, analyse and apply optimization methods for continuous optimization problems. The project work consists of a computer implementation of one or more self-chosen optimization methods and the application to one or more application problems. The focus could be more on the algorithmic side, e.g. on comparing different algorithm variants, or more on the modelling side, e.g. formulating and solving on interesting optimization problem. The project results are a documented computer code, a project report, and a public presentation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Zu erbringende Prüfungsleistung / Examination result</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Written documentation of the project results</td>
</tr>
<tr>
<td>Result of the project and the basis for the project grade is a documented computer code, a report and a brief public presentation in the lecture at the end of the semester.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Zu erbringende Studienleistung / Course Achievement</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to participate in the course &quot;Numerische Optimierung / Numerical Optimization - Lecture&quot; in order to be admitted to the final module exam.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Benufung / Grading</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated as 100% of the written report of the project.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Gewichtung der Prüfungsleistung / Weight of examination result</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
Modulhandbuch M.Sc. Mikrosystemtechnik – Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Numerische Optimierungsoftware Projekt / Numerical Optimization Software Project</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5248</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture und Exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Zwingende Voraussetzungen: Mandatory preconditions**
- Mathematics such as Calculus, Linear Algebra, basic programming skills, and some familiarity with optimization
- previous spring/summer schools on "numerical optimal control" or one of the lectures "optimal control and estimation" or "numerical optimization"

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>3 project</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 hours Full-time attendance course of study + 48 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology
### Lernziele / Learning target

Students understand computational methods for solution of optimization problems and can independently apply the acquired knowledge.

### Inhalte Projekt / Content of the project

The course covers linear, quadratic, conic and nonlinear programming methods and introduces the participants to numerical software packages for each of these problem classes. Also, benchmarking techniques are presented. The course consists of lectures, computer exercises and a project. Theoretical and computer exercises accompany the lecture to deepen the understanding. In the week(s) after the course, participants work on individual projects regarding a software performance comparison, and hand in a written report.

### Zu erbringende Prüfungsleistung / Examination result

Written report
In the week after the course, students work on individual projects regarding a specific software performance comparison, and hand in a written report which is the basis for the evaluation.

### Benotung / Grading

The module grade is calculated as 100% of the written report of the project.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5249</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörgige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). An optimization course (e.g. „Optimal Control and Estimation“) is an advantage, but not necessary.</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 lecture + 2 exercises |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Sustainable Systems Engineering
    - Informationstechnik / Information Processing Technology
**Lernziele / Learning target**

Aim of this intensive course is to give both theoretical background and hands-on practical knowledge in numerical methods to solve optimal control problems for offline and embedded applications such as linear and nonlinear model predictive control. In particular, participants shall become able to formulate and to numerically solve optimal control problems with help of modern computing tools.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>The course covers all topics relevant for the formulation and practical solution of embedded optimal control problems (OCP). It starts by recalling concepts from numerical simulation of ordinary differential equation models (ODE) and differential algebraic equations (DAE) as well as concepts from convex and nonlinear optimization. The major focus of the course is on direct approaches, in particular on direct collocation, direct single and direct multiple shooting. A second focus is on important application classes such as parameter and state estimation and nonlinear model predictive control (NMPC) and embedded optimization algorithms. The course also treats several implementation details such as the choice of discretization schemes and quadratic programming (QP) solvers. All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python, CVXPY and CasADi (all open-source), and participants are recommended to bring a laptop. In the second week of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards at end of the course, after the written exam.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>The computer exercises are integral parts of the summer course on numerical optimal control. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Written or oral examination</td>
</tr>
<tr>
<td>• Graded exercises/practical exercises</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the</td>
</tr>
</tbody>
</table>
module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

**Modul / Module**

**Oberflächenanalyse – Laboratory / Surface Analysis Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5311</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

**Lernziele / Learning target**

Microsystems – especially those for microfluidics – are dominated by their surfaces due to their surface to volume ratio. This strong influence of surfaces is also important for devices e.g. sensors that are in contact with biological fluids. Surface analytical methods are, hence, often at the center of research questions in microsystems engineering. The Surface Analysis Laboratory introduces selected methods in this field and discusses strengths and limitations of each technique. It concentrates on surface analytical questions which are relevant for the life sciences.
### Inhalte Praktikum / Content of the laboratory

| Topic 1: Determination of the layer thickness and roughness of biocompatible coatings |
| Experiment 1: Using ellipsometry and x-ray reflectometry to determine the thickness of hydrogel coatings |

| Topic 2: Wetting of surfaces – Surface free energies |
| Experiment 2: Measurement of the contact angles of test liquids in various surfaces; Determination of the surface free energy using the Zisman method |
| Experiment 3: Generation and characterization of microarrays on various surfaces |

| Topic 3: Proteins / peptides on surfaces |
| Experiment 4: Measurement of the adsorption of blood proteins on surfaces using Surface Plasmon Resonance |
| Experiment 5: Characterization of the structure of protein layers using Fourier Transform Infrared Spectroscopy |

| Topic 4: DNA at surfaces |
| Experiment 6: Visualisation of DNA on mica using the Atomic Force Microscope |

### Zu erbringende Prüfungsleistung / Examination result

Before each experiment there will be an oral examination and for each experiment the student has to submit a written laboratory report.

### Benotung / Grading

The module grade will be determined from the average of the grades of the oral examinations and the laboratory reports.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture notes
## Optik-Laboratory Grundlagen / Basic Optics Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5213</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics and mathematics; Knowledge in Micro-optics</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

### Lernziele / Learning target

The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.

At the completion of the course, the successful student should possess:
- the ability to analyze measurement data and estimate errors;
- the ability to apply error propagation methods;
- the ability to assemble and align optical systems;
- a basic understanding of optical design methods;
- the ability to apply optical measurement techniques;
- the ability to apply analytical and graphical techniques for analyzing optical images.

### Inhalte Praktikum / Content of the laboratory

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:
- Statistics and data analysis
- Error propagation
- Focal length of lenses
- Focal length of lens systems
- Construction of a microscope
- Diffraction from gratings
- Newton’s rings
- Fiber optics
- Construction of an interferometer
- Polarization

### Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

### Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

In English:
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- S. Sinziger & J. Jahns: Microoptics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- D. Malacara: Optical shop testing
- W.J. Smith: Practical optical system layout

In German:
- E. Hecht: Optik
- Walcher: Laboratory der Physik
- Westphal: Physikalisches Laboratory
- Geschke: Physikalisches Laboratory
## Modulhandbuch M.Sc. Mikrosystemtechnik – Optik-Laboratory

### Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>11LE50MO-5217</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Dr. H. Zappe</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Einrichtung: Organisational unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modultyp: Module Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Module</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moduldauer: Module duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen: Connected events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprache: Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlene Voraussetzungen: Recommended preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic knowledge in physics and mathematics; Knowledge in Micro-optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 and 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Laboratory + 2 Laboratory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand: Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 hours (60 Hours Full-time attendance course of study + 300 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

### Lernziele / Learning target

**Basic Optics Laboratory:**
The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in
making optical measurements.

At the completion of the course, the successful student should possess:
- the ability to analyze measurement data and estimate errors
- the ability to apply error propagation methods
- the ability to assemble and align optical systems
- a basic understanding of optical design methods
- the ability to apply optical measurement techniques
- the ability to apply analytical and graphical techniques for analyzing optical images

Advanced Optics Laboratory:
The Advanced Optics Laboratory Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the curriculum of the 'Optics Lab Course I' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of modern optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:
- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in modern optical setups

Inhalte Praktikum / Content of the laboratory

Basic Optics Laboratory:
One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:
- Statistics and data analysis
- Error propagation
- Focal length of lenses
- Focal length of lens systems
- Construction of a microscope
- Diffraction from gratings
- Newton's rings
- Fiber optics
- Construction of an interferometer
- Polarization

Advanced Optics Laboratory:
This advanced Optics Lab Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the knowledge acquired in the 'Basic Optics Laboratory' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:
- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in optical setups

Table of contents:
- Anamorphic imaging
- Dynamically addressable gratings
- Whispering gallery resonators
- Michelson interferometer and coherence
- Three dimensional light distribution in a 6f system
- Diode pumped solid state laser

Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required. The final module grade is determined from an average of the grades of the individual reports of both courses. All experiments must be performed and a lab report written.

Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports in both courses.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

In English:
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- S. Sinziger & J. Jahns: Microoptics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- D. Malacara: Optical shop testing
<table>
<thead>
<tr>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>• W.J. Smith: Practical optical system layout</td>
</tr>
<tr>
<td>In German:</td>
</tr>
<tr>
<td>• E. Hecht: Optik</td>
</tr>
<tr>
<td>• Walcher: Laboratory der Physik</td>
</tr>
<tr>
<td>• Westphal: Physikalisches Laboratory</td>
</tr>
<tr>
<td>• Geschke: Physikalisches Laboratory</td>
</tr>
</tbody>
</table>
### Modul / Module

**Optimale Steuerung und Estimation / Optimal Control and Estimation**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5241</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

| Empfohlenes Fachsemester:: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Semester week hours | 4 Lecture 2 Übung |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 180 hours (84 Hours Full-time attendance course of study + 96 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Cyber.Physical Systems
  - Kognitive Technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
Lernziele / Learning target

Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Riccati Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

Inhalte Vorlesung / Content of the lecture

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearization of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

Inhalte Übung / Content of the exercises

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The
grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

## Optimization/Optimierung

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimization/Optimierung</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-720</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Prof. Dr. F. Kuhn und Prof. Dr. T. Brox</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Einrichtung: Organisational unit</th>
<th>Chair for Algorithms and Complexity and for Image Processing and Computer Graphics</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Modultyp: Module Type</th>
<th>Elective Module</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Moduldauer Module duration</th>
<th>1 term</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen: Connected events</th>
<th>Lecture and exercises</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sprache: Language</th>
<th>German</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Empfohlene Voraussetzungen: Recommended preconditions</th>
<th>Kenntnisse aus den Modulen</th>
</tr>
</thead>
</table>

- Einführung in die Programmierung
- Informatik II – Algorithmen und Datenstrukturen
- Fortgeschrittene Programmierung
- Mathematik I für Ingenieure und Informatiker
- Mathematik II für Informatiker

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>4</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>1 Lecture + 1 Übung</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Angebotsfrequenz: Regular cycle</th>
<th>only in the summer term</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand: Workload</th>
<th>90 hours</th>
</tr>
</thead>
</table>

(28 Hours Full-time attendance course of study + 62 Hours Self-study)

<table>
<thead>
<tr>
<th>Verwendbarkeit der Veranstaltung / Usability of the module</th>
</tr>
</thead>
</table>

Mandatory Module for students of the study program
- Bachelor of Science in Informatik

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
Lernziele / Learning target

Die Studierenden lernen, welche Optimierungsprobleme es gibt und wie sie gelöst werden können. Sie sollen die Schwierigkeit von Optimierungsproblemen analysieren und einschätzen lernen und in die Lage versetzt werden, die besprochenen Optimierungsverfahren in Anwendungsfällen einzusetzen.

Inhalte Vorlesung / Content of the lecture


Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingeschrieben.
- Bachelor of Science in Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingeschrieben.
- Bachelor of Science in Informatik, Prüfungsordnungsversion 2012: Die Modulnote für das Modul "Graphentheorie und Optimierung" (Teilmodul Optimierung) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingeschrieben.
- Bachelor of Science in Mikrosystemtechnik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingeschrieben.
- Master of Science in Microsystems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingeschrieben.
- Master of Science in Mikrosystemtechnik, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingeschrieben.
## Optimierung von Fertigungsverfahren / Advanced engineering

### Nummer: Number
11LE50MO-5607

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Einrichtung: Organisational unit</th>
<th>Modultyp: Module Type</th>
<th>Modulverantwortlicher: Responsible person</th>
<th>Einrichtung: Organisational unit</th>
<th>Modultyp: Module Type</th>
<th>Modulverantwortlicher: Responsible person</th>
<th>Einrichtung: Organisational unit</th>
<th>Modultyp: Module Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>N.N.</td>
<td>Chair for Process Technology</td>
<td>Elective Module</td>
<td>1 term</td>
<td></td>
<td></td>
<td>N.N.</td>
<td>Chair for Process Technology</td>
<td>Elective Module</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen: Connected events</th>
<th>Sprache: Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlene Voraussetzungen: Recommended preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Statistical Basics</td>
</tr>
<tr>
<td>• Fundamentals of Manufacturing Technology</td>
</tr>
<tr>
<td>• Processes of microsystem technology (clean room fabrication and conventional environment)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>Angebotsfrequenz: Regular cycle</th>
<th>Arbeitsaufwand: Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Lecture</td>
<td>Only in the summer term</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

- Learn how to make complex processes controllable with minimum experimental effort a maximum on process significance.
- How to optimize technical results towards no rejects, towards zero failure production.
- Extension of the mathematical methods to organizational structures and management.
### Inhalte Vorlesung / Content of the lecture

- Design of Experiments
- Tolerancing and tolerance stacking
- Failure Mode and Effects Analysis
- Continuous Improvement Process
- General business and management methods for this purpose

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- George E. P. Box, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building (Wiley Series in Probability and Statistics)
- Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes using Failure Mode and Effects Analysis Hardcover – May 15, 2012 by Carl Carlson
**Modul / Module**

**Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5211</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. A. Gombert</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
</tbody>
</table>

(32 Hours Full-time attendance course of study + 58 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

The objective of this module is learning the fundamentals of technics and physics with respect to the interaction of electro-magnetic waves with predominantly periodically...
structured matter. The students will be enabled to predict the qualitative optical properties of micro and nano structured materials with the taught methods. The superior learning target is to master the fundamental capabilities to design diffractive optical elements and optical elements based on subwavelength structures as well as to know their respective technical applications. The students will obtain the engineering know-how for micro and nano optical elements as used in micro systems technology.

Inhalte Vorlesung / Content of the lecture

Micro and nano structures have optical properties that differ from macroscopic bodies. The interaction between incident light or more generally incident electromagnetic radiation may lead to a modification of the propagation direction, the polarisation, and the spectral signature of absorption, reflection or transmission. In micro systems or similar technologies these phenomena can be used on purpose or need to be considered when manufacturing micro and nano structures. In this lecture we will work on the theoretical fundamentals as well as on selected applications.

Topics:
- Calculating with complex amplitudes
- Energy transfer at boundaries
- Two beam interference
- Huygens’ principle
- Fresnel’s zone construction
- Introduction into Fourier optics
- Kirchhoff-Fresnel diffraction integral
- Fresnel diffraction
- Fraunhofer diffraction
- Introduction into diffraction gratings
- Spectroscopic gratings
- Theory and applications of subwavelength gratings
- Photonic crystals
- Resonant structures in metals
- Production technologies for micro structures with optical functions

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- E. Hecht: Optics, Addison-Wesley, 1989
Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking

Nummer: Number 11LE50MO-5219

Modulverantwortlicher: Responsible person Prof. Dr. A. Rohrbach

Einrichtung: Organisational unit Chair for Bio- and Nanophotonics

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlenes Fachsemester:: Recommended term of study 4 ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 3 Lecture + 2 Exercises Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 180 hours (70 Full-time attendance course of study + 110 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

Optical traps and optical micro-manipulation techniques do have the potential to play a key role in future micro- and nanosystems in conjunction with the life sciences. In this lecture the students should learn what is doable with optical forces, where physical limits are and what
is limited by nowadays technology. Besides fascinating fundamental research various applications related to biology or fluctuation based systems are presented. The lecture is manifold and teaches basics in optics, statistical physics and biology/biophysics.

Inhalte Vorlesung / Content of the lecture

1. Introduction
2. Light - Information carrier and actor
3. About microscopy
4. Light scattering
5. Optical forces
6. Tracking beyond the uncertainty
7. Brownian motion and calibration techniques
8. Photonic force microscopy
9. Applications in cell biophysics
10. Time- multiplexing and holographics optical traps
11. Applications in microsystems technology
12. Applications in nanotechnology

Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

Bewertung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of
2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the
fundamentals of light-matter interaction as well as effects that are widely used in many applications. Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.

Inhalte Vorlesung / Content of the lecture

1. Classification of optical materials
2. Fabrication
3. Interaction of light and matter
4. Pulse propagation in dispersive materials
5. Birefringence
6. Faraday effect
7. Nonlinear-optical effects
8. Pockels effect
9. Kerr effect
10. Photoactivity
11. Frequency conversion
12. Optical parametric oscillators
13. Optical whispering galleries

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Literatur / Literature

- B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“
- A. Yariv, "Photonics: Optical Electronics in Modern Communications"
## Modul / Module

### Optische MEMS / Optical MEMS

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nummer: Number</td>
<td></td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Gisela and Erwin Sick Chair of Micro-optics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Physical Optics</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Circuits and Systems
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Photonics
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Photonics
    - Personal Profile

### Lernziele / Learning target

- Theoretical understanding of fundamental optical phenomena exploited by the MOEMS technology
- Acquisition of the essential skills necessary for the design, microfabrication, modeling, and characterization of MEMS/MOEMS components
- A comprehensive knowledge of MOEMS based commercial systems and a basic...
Understanding of the particular applications enabled by MOEMS

### Inhalte Vorlesung / Content of the lecture

**Module 1: MOEMS Fundamentals**
- Optics Review
- MEMS Manufacturing Techniques
- Actuators and Position Sensing
- Design and Modeling
- Test and Characterization

**Module 2: MOEMS Devices**
- Micromirrors
- Tunable Gratings
- Active Microlenses
- Tunable Optical Resonators

**Module 3: MOEMS Systems**
- Display and Imaging Systems
- MOEMS in Telecommunication Networks
- Scientific Instrumentation

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

MEMS and MOEMS Related Books
- An Introduction to Microelectromechanical Systems Engineering by N. Maluf
- Microsystems Design by Stephen Senturia
- Micromachined Transducers Sourcebook by G. Kovacs
- Fundamentals of Microfabrication by Marc Madou
- Micro Electro Mechanical System Design by J. Allen
- Analysis and Design Principles of MEMS Devices by Minhang Bao
- The MEMS Handbook by Mohamed Gad-el-Hak
- MOEMS: Micro-Opto-Electro-Mechanical Systems by Manouchehr E. Motamedi
- Foundations of MEMS by Chang Liu
- MEMS & Microsystems by Tai-Ran Hsu

Scientific Journals
- Journal of Microelectromechanical Systems / IEEE
- Journal of Micromechanics and Microengineering / IOP
- Journal of Micro/Nanolithography, MEMS, and MOEMS / SPIE
- Microsystem Technologies / SPRINGER
- Sensors and Actuators A-Physical / ELSEVIER
- Applied Optics / OSA
- Optics Letters / OSA
- Optics Express / OSA
- Applied Physics Letters / AIP
- Journal of Biomedical Optics / SPIE
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nummer: Number</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
</tr>
<tr>
<td>Sprache: Language</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

The students gain knowledge about different optical measurement techniques for shape determination of objects or for material characterization. They achieve a deeper understanding of the physical background. Consequently, the participants are able to estimate the fundamental and technological limitations of the methods presented. This enables the students to select an appropriate optical measurement technique for a given task. Furthermore, the participants get trained in preparing and presenting excellent talks.
### Inhalte Seminar / Content of the seminar

During the first meeting the organizers will present a list of topics from which each active participant of the seminar can select one. For each topic literature will be provided. Starting with this material the active participants of the seminar will familiarize themselves with the content. This will be done by discussions as well as by further literature search. Based on the accumulated knowledge, an outline for talks will be made and finally the viewgraphs will be prepared. Then the talk will be presented in the seminar. Typical duration of the talk is 30 minutes. After the talk there will be a discussion about the content. And as a second part of the discussion technical issues of the talk will be analyzed. Finally, a short written summary of the talk will be prepared. Talks can be given in German or English.

This semester, the following topics are available:
- 3d-shape determination
- Optical microresonators for sensing
- Terahertz waves for material characterization
- Photoacoustic spectroscopy
- Laser spectroscopy
- Fluorescence spectroscopy
- and more

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

The advisor will provide some reading material as a starting package.
### Modul / Module

**Optische Mikrosensoren / Optical Micro-Sensors**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5711</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Brandenburg</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Einrichtung: Organisational unit</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Moduldauer Module duration</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Vorlesung</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>(28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

### Lernziele / Learning target

Kenntnis der Prinzipien miniaturisierter optischer Sensoren, Vertiefung bei den Gebieten Wegsensorik, Drehratensensoren sowie chemische und biochemische Sensoren.

### Inhalte Vorlesung / Content of the lecture

- Vorbereitende Inhalte: Grundlagen der Optik (kurze Wiederholung), Lichtwellenleiter.
- Optische Grundlagen für die Sensorik: Interferometrie, Sagnac-Effekt, Spektroskopie, Fluoreszenz.
- Detaillierte Darstellung der Funktion und der technologischen Realisierung von
Modulhandbuch M.Sc. Mikrosystemtechnik – Optische Mikrosensoren / Optical Micro-Sensors

Wegsensoren, Drehratensensoren, Miniaturspektrometern und fluoreszenzoptischen Sensoren sowie Microarray-Technologien.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- G. Schröder: Technische Optik, Vogel-Verlag, Würzburg 1980
- T. Tamir (Hrsg.): Guided wave optoelectronics, Springer-Verlag 1988
- W. Schmidt: Optische Spektroskopie, VCH Verlagsgesellschaft Weinheim 1994
Modul / Module

Partikelsimulationsmethoden / Particle Simulation Methods

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5505a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Simulation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / Learning target

Lecture:
The students will learn about alternative approaches to the simulation of hydrodynamic phenomena relevant for microsystems engineering. They will have a basic understanding of Molecular Dynamics, Dissipative Particle Dynamics and Smoothed Particle Hydrodynamics. They will understand the relation to continuum methods for fluid dynamics. The students will acquire the knowledge on how to apply particle methods to specific problems in microfluidics simulation.
Practical exercises:
The will be able to compile an adequate model for the description of the phenomenon under investigation. They will be able to decide which of the respective particle methods detailed in the lecture to apply for the solution. The students will understand the meaning of particle simulation methods as an experimental tool to investigate materials behaviour through the usage of a particle simulation program and the solution of modeling and simulation assignment.

Inhalte Vorlesung / Content of the lecture

The lecture will cover the following topics:
- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Molecular Dynamics (MD): Basics
- MD: Numerical Techniques
- Dissipative Particle Dynamics (DPD)
- Smoothed Particle Hydrodynamics
- Energy conserving DPD
- Degrees of freedom internal to dissipative particles

Inhalte Übung / Content of the exercises

These exercises will accompany the topics given in the course on Advanced Topics in Simulation: Particle Methods. The exercises will focus on problems to be solved with the software tool MOLDYN, developed at IMTEK Simulation. Moldyn uses XML input language and provides a wide range of tools for the analysis of results. Direct graphical output can be followed on the computer screen. An interface to Paraview is included to observe different states of the simulation and to produce videos from the results. The students will be assigned with a project to be solved by MOLDYN. To this end a detailed introduction on the usage of MOLDYN will be given.
To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Andrew R. Leach, Molecular modelling: principles and applications, Prentice Hall (2001)
Modul / Module

**Photonische Mikroskopie / Photonic Microscopy**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5901</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Bio- and Nanophotonics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Lecture + 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (80 Hours Full-time attendance course of study + 100 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile

### Lernziele / Learning target

The student should learn how to guide light through optical systems, how optical information can be described very advantageously by three-dimensional transfer functions in Fourier space, how phase information can be transformed to amplitude information to generate image contrast. Furthermore, one should experience that wave diffraction is not reducing the information and how to circumvent the optical resolution limit. The student should learn to distinguish between coherent and incoherent imaging, learn about modern techniques using self-reconstructing laser beams, two photon excitation, fluorophores depletion through stimulated emission (STED) or multi-wave mixing by coherent anti-Stokes Raman scattering (CARS). The module has an ongoing emphasis on applications, but nevertheless presents a mixture of fundamental physics, compact mathematical descriptions and many examples.
and illustrations. The lecture aims to encompass the current state of a scientific field, which will influence the fields of nanotechnology and biology/medicine quite significantly.

### Inhalte Vorlesung / Content of the lecture

1. Microscopy: History, Presence and Future
2. Wave- and Fourier-Optics
3. Three-dimensional optical imaging and information transfer
4. Contrast enhancement by Fourier-filtering
5. Fluorescence – Basics and techniques
6. Point scanning and confocal microscopy
7. Microscopy with self-reconstructing beams
8. Optical tomography
9. Nearfield and Evanescent Field Microscopy
10. Super-resolution using structured illumination
11. Multi-Photon-Microscopy
12. Super resolution imaging by switching single molecules

### Inhalte Übung / Content of the exercises

The tutorials help the student to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Modulhandbuch M.Sc. Mikrosystemtechnik – Photovoltaic Energy Conversion for engineers

Modul / Module

Photovoltaic Energy Conversion for engineers

Nummer: 11LE50MO-5712

Modulverantwortlicher: Prof. Dr. S. Glunz

Einrichtung: Chair for Photovoltaic Energy Conversion (INATECH)

Modultyp: Elective Module

Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture

Sprache: English

Empfohlene Voraussetzungen:

Basic knowledge of semiconductor physics and technology.

Empfohlenes Fachsemester: 2

ECTS-Punkte: 3

SWS: 2 Lecture

Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 90 hours

(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / Learning target

This module gives a general overview of the components of photovoltaic energy systems
and the chances of this renewable energy.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>To be admitted to the final examination, the lecture at each lecture date must be visited. Unexcused absence leads to a non-admission to the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to attend the lecture regularly in order to be admitted to the final module exam.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II

**Nummer:** 11LE50MO-5718

**Modulverantwortlicher:** Prof. Dr. S. Glunz

**Einrichtung:** Chair for Photovoltaic Energy Conversion (INATECH)

**Modultyp:** Elective Module

**Moduldauer:** 1 term

**Zugehörige Lehrveranstaltungen:** Lecture

**Sprache:** English

**Empfohlene Voraussetzungen:**
- Photovoltaic Energy Conversion for engineers I
- Halbleiterphysik/Semiconductor Physics

**Empfohlenes Fachsemester:** 2

**ECTS-Punkte:** 3

**SWS:** 2 Lecture

**Angebotsfrequenz:** Only in the summer term

**Arbeitsaufwand:**
- 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

**Lernziele / Learning target**

The focus of the first part of this module series "Photovoltaic Energy Conversion for engineers I" was on the fundamentals of solar cells and on the technology of crystalline silicon solar cells. This second part "Photovoltaic Energy Conversion for engineers II" focusses on alternative photovoltaic technologies, system aspects, grid integration and the
### Inhalte Vorlesung / Content of the lecture

The lecture "Photovoltaic Energy Conversion II" starts with a short wrap-up of the contents of the preceding lecture and then focuses on:

- Thin-film PV technologies (CIS, CdTe, ...)
- Organic solar cells
- Perovskite solar cells
- Multijunction solar cells (Tandem)
- III/V-based PV and concentrator applications
- Photonics for solar cells (upconversion, ultra light rapping ...)
- System technology (inverters, storage)
- Grid integration (smart grids, ...)
- Economy of Photovoltaics

The students have to attend the lecture regularly in order to be admitted to the final module exam.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its
ECTS-points in the calculation of the overall grade.

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Würfel, Physik der Solarzelle, Spektrum - Akademischer Verlag 2000</td>
</tr>
<tr>
<td>A. Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner 1997</td>
</tr>
<tr>
<td>M.A. Green, Solar Cells, University of New South Wales 1982</td>
</tr>
<tr>
<td>Konrad Mertens, Photovoltaik, Hanser 2011</td>
</tr>
<tr>
<td>Jenny Nelson, The physics of solar cells, Imperial College Press 2008</td>
</tr>
</tbody>
</table>
Modul / Module

Piezoelektrische und dielektrische Wandler / Piezoelectric and dielectric transducers

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5713</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for the Design of Microsystems</td>
</tr>
<tr>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohle Voraussetzungen: Recommended preconditions

Mechanics and electronics should be known from bachelor studies

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

Arbeitsaufwand: Workload

90 hours
(42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

You will...
- be able to explain the physical effects that lead to electro-mechanical coupling
- be able to use the linear coupled theory to model dielectric and piezoelectric transducers
- be able to describe nonlinear effects and some ways to model them
- know several applications of dielectric and piezoelectric transducers and their
<table>
<thead>
<tr>
<th>advantages and disadvantages</th>
</tr>
</thead>
</table>

### Inhalte Vorlesung / Content of the lecture

- Introduction to Piezoelectrics (material science)
- Linear theory of Piezoelectrics
- Nonlinear Effects, high field effects, hysteresis
- Other transduction mechanisms (Electrets, Electrostriction)
- Applications

### Inhalte Übung / Content of the exercises

To qualify for the exam at least one of the exercise tasks must be solved on the chalk board during an exercise session.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
</thead>
</table>
# Modul / Module

**Polymere in der Membrantechnik / Polymers in Membrane Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5114</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for the Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

## Lernziele / Learning target

- Gain awareness for separation needs and sustainability impact
- Understand principles of separation
- Understand membrane fabrication and (polymeric) membrane material properties
- Apply polymeric surface modifications to mitigate material limitations and enable new processes
The lecture will focus on polymeric materials for membrane separation technologies. The scope of applications that will be discussed ranges from water to oil & gas, biotech, dialysis to food with a focus on water filtration technologies. Creating awareness for major societal challenges like clean water supply, health care / quality of life and minimization of energy consumption and for contributions that membrane technologies can offer to sustainable solutions for these challenges will be key learning objectives. Focus will be on materials and membrane fabrication / post-modification processes as well as on the underlying principles of separation. Process engineering will be of minor importance. The lecture will concentrate on cognitive levels ‘understanding’ and ‘application’ (Bloom’s taxonomy), case studies will touch upon higher levels.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung</th>
<th>Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung</th>
<th>Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung</th>
<th>Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
<td></td>
</tr>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
<td></td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
<td></td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
<td></td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
<td></td>
</tr>
<tr>
<td>• Master of Science in Sustainable Materials Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various materials are available on the website Homepage: <a href="http://www.imtek.de/cpi">http://www.imtek.de/cpi</a></td>
<td></td>
</tr>
</tbody>
</table>
## Modul / Module

### Projektmanagement für Ingenieure / Project management for engineers

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5803</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Wallrabe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microactuators</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English and German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

### Lernziele / Learning target

Students shall learn the basic ideas and techniques of project management and apply them to representative examples. They shall realize that planning tasks isn’t always as clear-cut as in engineer courses. A project can be structured in different ways. One plan isn’t necessarily better than the other. Instead, one approach might be more practical or provide a better overview than another. Additionally, the students shall gain insight into the soft skills of project management, i.e. how to deal with operating persons, namely the project team as a social system.
### Inhalte Seminar / Content of the seminar

The course comprises a mixture of lecture and group work with short presentations of the obtained project plans. The different phases of a project and its respective project management, i.e. project assignment, planning, execution and completion of a project, is presented as an introduction into the field. The different roles of people coping with the project, i.e. initiator or customer, project manager and staff, and their duties are presented, and their responsibilities analysed.

Various planning techniques and plans will be introduced: project environment analysis, risk analysis, work breakdown structure, Gantt chart and SWOT analysis. The financial budgeting of a project will be shown: existing cost factors, their estimation and what exactly has to be considered.

In addition, the more technical aspect of project planning will be supplemented with soft skills, like how to lead a discussion, mediation, etc. MS Project will be used to make the project management simpler. With its help project plans for fictitious projects will be developed. The presented lecture content will be visualized with two fictitious projects. The students will have to implement the learning matter in individual and team work. The projects are a journey round the world with fellow students after graduation and a virtual Master thesis.

### Zu erbringende Prüfungsleistung / Examination result

written examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Regularly updated lecture notes are available.
# Modul / Module

## Quantenmechanik für Ingenieure / Quantum mechanics for engineers

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystems Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Semiconductor Physics or Physical Electronics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile

## Lernziele / Learning target

The goal is to introduce the students to the main effects of quantum mechanics relevant in
technical micro and nano devices. Current semiconductor components in which quantum mechanics plays a role are discussed in depth. The course successively develops the basic mathematical methods required to solve one, two and three-dimensional problems. The understanding is deepened by practical exercises.

### Inhalte Vorlesung / Content of the lecture

- **Introduction:** Historical overview, unsolved problems at the beginning of the 20th century, probability amplitudes, uncertainty relation
- **Wave mechanics:** Schrödinger equation, separation of variables, free particle, reflection at wall, potential step, transfer matrix method, wave packets,
- **Tunneling:** Principle, semiconductor tunneling devices, potential barriers, WKB approximation, triangular potential wall
- **Bound states, resonances, and band structure:** Potential well, tunneling between wells, infinite series of potential wells
- **Single electron transistors:** Double-junction SETs, Coulomb barrier, Coulomb staircase, gate-biased SETs, single-electron turnstile, single-electron pumps

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- **Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011:** The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- **Master of Science in Embedded Systems Engineering, Academic regulations of 2012:** The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- **Master of Science in Informatik, Academic regulations of 2011:** The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- **Master of Science in Microsystems Engineering, Academic regulations of 2009:** The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- **Master of Science in Mikrosystemtechnik, Academic regulations of 2009:** The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Lecture notes
Modul / Module

Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers

Nummer: Number 11LE50MO-5804

Modulverantwortlicher: Responsible person N.N.

Einrichtung: Organisational unit Chair for Process Technology

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Laboratory

Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study

ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 3 Laboratory

Angebotsfrequenz: Regular cycle Only in summer term

Arbeitsaufwand: Workload 90 hours (42 hours Full-time attendance course of study + 48 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

Lernziele / Learning target

Hands-on experience and deepening of obtained knowledge of the module “MST - Technologies and Process”

Inhalte Praktikum / Content of the laboratory

Cleanroom behavior and processing:
- Wafer handling
- Lithography sequence
- Cleaning
- Metal deposition (physical vapour deposition)
- Profilometry
- Lift-Off
- Wafer backside processing
- Electroplating
- Characterization
- Acquisition of relevant processing data and recording

### Zu erbringende Prüfungsleistung / Examination result

5 short tests and lab report are required.

### Benotung / Grading

The module grade is calculated from the average of the grades of the required tests.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- H. Reinecke, MST Technologies and Processes, lecture
- W. Menz, J. Mohr, O. Paul Microsystems Technology, Wiley VCH
- M. Madou, Fundamentals of Microfabrication, CRC Press
- S. M. Sze, Physics of Semiconductor Devices, Wiley VCH
- J.W. Dini, Electrodeposition, Noyes Publications
### Rennautoregelung – Laboratory / Race Car Control Laboratory

<table>
<thead>
<tr>
<th><strong>Modulverantwortlicher:</strong></th>
<th>Prof. Dr. M. Diehl</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Einrichtung:</strong></td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td><strong>Modultyp:</strong></td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong></td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong></td>
<td>Laboratory</td>
</tr>
<tr>
<td><strong>Sprache:</strong></td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen:**
The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of "Modelling and System Identification" and/or "Optimal Control and Estimation" are recommended.

<table>
<thead>
<tr>
<th><strong>Empfohlenes Fachsemester:</strong></th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECTS-Punkte:</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>SWS:</strong></td>
<td>4 Laboratory</td>
</tr>
<tr>
<td><strong>Angebotsfrequenz:</strong></td>
<td>Each term</td>
</tr>
<tr>
<td><strong>Arbeitsaufwand:</strong></td>
<td>180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
Personal Profile
- Master of Science in Sustainable Systems Engineering
- Informationstechnik / Information Processing Technology

Lernziele / Learning target

Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

Inhalte Vorlesung / Content of the lecture

Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controlling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer.

The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

Zu erbringende Prüfungsleistung / Examination result

Project work:
- A working project result
- Project documentation and oral presentation

Benotung / Grading

The final module grade is determined from an average of the grades of the project work.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is tripleweighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
RF- und Mikrowellen Design Kurs / RF- and Microwave Design Course

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nummer:</strong> Number</td>
</tr>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
</tr>
</tbody>
</table>

**Zwingende Voraussetzungen:** Mandatory preconditions

The prior or parallel participation in either module "RF- and microwave devices and circuits" or "RF- and microwave circuits and systems" is required. No prior knowledge of the software is required.

**Empfohlenes Fachsemester:** Recommended term of study

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
</table>

**SWS:** Semester week hours

<table>
<thead>
<tr>
<th>2 Laboratory</th>
</tr>
</thead>
</table>

**Angbottsrequenz:** Regular cycle

| Only in the summer term |

**Arbeitsaufwand:** Workload

| 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

**Lernziele / Learning target**

The students will be enabled to understand, design and layout modern RF- and microwave components and systems by means of the electronic design environment Agilent Advanced Design System including the two- and three dimensional electromagnetic simulators.
Momentum and EMPro 3D. The detailed use of a complex RF-software environment is a dedicated target of this course. This includes the numerical analysis of complex passive and active devices, the design and layout of hybrid and integrated circuits, and their packaging and signal flow. The students will be competent to design and layout passive and active RF-structures including packages and interconnects and circuits of relevance to everyday communication and sensing. The competence includes in-depth understanding and treatment of complex microwave systems and of general system design including the treatment of complex modulated signal flows.

**Inhalte Praktikum / Content of the laboratory**

The Design Course: RF- and Microwave Systems deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high-level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterisation, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skript: Design Course: RF- and Microwave Systems, R. Quay, 2014 (will be provided at the beginning of the lecture)</td>
<td></td>
</tr>
</tbody>
</table>
Modul / Module

RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5215</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>PD Dr. R. Quay</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer:</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: | 5 |
| ECTS-Punkte: | 3 |
| SWS: | 2 Lecture |
| Angebotsfrequenz: | Only in the winter term |
| Arbeitsaufwand: | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / Learning target

The students will be enabled to understand concepts, devices, design, and functioning of modern RF- and microwave transceiver subsystems. This includes the understanding of basic RF-concepts, passive and active devices, circuits, functionalities, their critical figures-of-merrit, and the inclusion into modules. The students will be competent to analyse passive and active RF-structures and circuits, which are relevant for any system with an RF-
Modulhandbuch M.Sc. Mikrosystemtechnik – RF- und Mikrowellen
Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits

**Inhalte Vorlesung / Content of the lecture**

The lecture RF- and Microwave Devices and Circuits deals with the fundamentals of RF-devices and circuits. It comprises three parts: high-frequency/RF concepts and passive structures, active electronic RF-devices, and RF-circuits and modules. At the interface of modern electronics, dielectric wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern electronics and modern passive RF-technology to the understanding of RF-communication and sensing systems. The methodologies of RF-analysis, design of devices and circuits, and their basic figures-of-merit, their modelling and characterisation are introduced along with the demonstration of their relevance to modern RF-components and microsystems. This also includes a discussion of the underlying technology and many examples supported by RF-design tools from the microwave oven to today’s RF-applications in mobile communication in the iPod.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

RF- and Microwave passives
- Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999
RF- and Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5232</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. R. Quay</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>IMTEK</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modul dauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / Learning target

The students will be enabled to understand concepts, functioning, and design of modern complex RF-and microwave circuits and systems. This includes the understanding of basic RF-concepts, of more complex passive and active circuits, of modern antennas, of combined functionalities, data acquisition, and aspects of systems and communication theory. The students will be competent to analyse passive and active RF-structures and circuits, full RF-functions, analyze complex signal and data flows, and full system concepts
and data acquisition. System concepts for communication, such as for a full transmit-receive system, for remote sensing including imaging and radar, are presented and several examples discussed in detail.

**Inhalte Vorlesung / Content of the lecture**

The lecture RF- and Microwave Devices and Circuits deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high – level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterization, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
| - RF- and Microwave passives  
| - Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999  
| - Further reading material for systems is presented during the lecture. |
Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators

Nummer: Number 11LE50MO-5714

Modulverantwortlicher: Responsible person Prof. Dr. P. Woias

Einrichtung: Organisational unit Chair for the Design of Microsystems

Modultyp: Module Type Elective Module

Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language German

Empfohlenes Fachsemester:: Recommended term of study 2

ECTS-Punkte: ECTS-points 5

SWS: Semester week hours 2 lecture + 2 exercises

Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 150 hours (56 hours Full-time attendance course of study + 94 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / Learning target

Das Modul vermittelt grundlegendes Wissen zur elektronischen Schaltungstechnik verschiedener Mikrosensoren und Mikroaktuatoren. Es werden in einer Abfolge von Kapiteln zunächst die Grundlagen einiger wesentlicher elektronischer Bauelemente und Funktionsgruppen vermittelt. Anschließend werden kapitelweise mehrere Sensor- und
Aktormechanismen kurz vorgestellt, gefolgt von einer Erläuterung der wichtigsten Schaltungs konzepte für ihren Betrieb.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die Lecture ist in folgende Kapitel gegliedert:</td>
</tr>
<tr>
<td>• Einführung in elektronische Bauelemente und Funktionsblöcke (Diode, Bipolar transistor, Stromquellen, Stromspiegel, Bandgap-Referenz, Operationsverstärker)</td>
</tr>
<tr>
<td>• Stromliefernde Sensoren (Photodiode, amperometrische Elektrode)</td>
</tr>
<tr>
<td>• Spannungsliefernde Sensoren (Ionsensitiver Feldeffekttransistor)</td>
</tr>
<tr>
<td>• Resistive Sensoren nach dem Wheatstone-Brückenprinzip (Druck, Beschleunigung)</td>
</tr>
<tr>
<td>• Kapazitive Sensoren (Druck, Beschleunigung, Feuchte)</td>
</tr>
<tr>
<td>• Kapazitive Aktoren (elektrostatisch, piezo)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
**Modulhandbuch M.Sc. Mikrosystemtechnik – Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals**

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

**Verwendungbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering  
  - Personal Profile
- Master of Science in Informatik  
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik  
  - Life Sciences: Biomedical Engineering  
  - Personal Profile
- Master of Science in Microsystems Engineering  
  - Life Sciences: Biomedical Engineering  
  - Personal Profile

**Lernziele / Learning target**

The objective of the module is to show, how signal processing and analysis methods can add additional information to the classical ways of interpreting brain signals measured by electroencephalography (EEG) or magnetoencephalography (MEG).
This goes beyond the basic signal processing methods to separate the signal from background noise. General techniques for pattern recognition will be presented and how they are tailored for the daily use in clinical practice or neuroscience research. As a result students will have knowledge of general tools in pattern recognition in recordings of brain signals and how to adapt them to the requirements of the specifics needs in clinical use or for research projects.
The second part of the module will add modelling to the signal analysis to perform the localization of generators of brain activity. Different approaches of modelling of the head and the generators of the brain activity will be introduced. The objective is to provide the students with knowledge about different modelling levels and strategies about the selection of generator models, which are appropriate for a given source localization task.

**Inhalte Vorlesung / Content of the lecture**

The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies.

a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously.

b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy.

c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic.

In detail following strategies will be presented:

a) Heuristics

b) Template matching

c) Wavelet transformation

d) Hilbert transformation

e) Background and target modelling

f) Artificial neural networks

A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements.

The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the forward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented:

a) Spherical model

b) Boundary element model

c) Finite element model

Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination
Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Siliziumbasierte Neurosonden / Silicon-based Neural Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher / Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung / Organisational unit</td>
<td>Chair for Microsystem Materials</td>
</tr>
<tr>
<td>Modultyp / Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer / Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen / Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache / Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fachsemester / Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte / ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS / Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz / Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand / Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)</td>
</tr>
</tbody>
</table>

---

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

---

**Lernziele / Learning target**

Students are offered a detailed overview of silicon-based probe arrays applied in fundamental neuroscientific research. They learn how these probes can be combined with specific materials to cover a broad range of needed functionalities. The students get familiarized with the basic requirements in view of system layout and function. They learn the fabrication technologies used to realize probes and systems.

---

**Inhalte Vorlesung / Content of the lecture**

- Introduction – Basic requirements of the field of neuroscience
- Electrical probes
- Fluidic probes
- Optical probes
- Chemotrodes
- IC technologies for signal amplification and data processing
- Assembly technologies

In order to be admitted to the final module exam regular attendance in the lecture is required. The presence in the lecture is monitored by an attendance list.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Recent conference and journal contributions
### Modul / Module

**Spektroskopische Methoden / Spectroscopic Methods**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5717</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Thin-film Gas Sensors</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitssaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture

Spektroskopische Anwendungen finden sich einer Vielzahl von Industrien, der

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.</td>
</tr>
</tbody>
</table>
## Systemtheorie und Regelungstechnik II / Systems theory and automatic control II

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5234</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Systems Control and Optimization</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>irregular</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

### Lernziele / Learning target

Students understand important structures used in practice and can independently apply the acquired knowledge. In addition, they master fundamental methods to describe, analyse and control discrete-time systems and multivariable systems. Furthermore, students can design...
model-based controllers and understand important concepts of nonlinear control.

**Inhalte Vorlesung / Content of the lecture**

Based on the Bachelor module "Systemtheorie und Regelungstechnik", advanced methods are discussed to describe, analyze, and control dynamic systems. The course consists of four parts:

The first part focuses on linear single-input single-output (SISO) systems. The methods derived in "systems theory and automatic control I" for continuous-time systems are transferred to discrete-time systems. In particular, the structure of a digital control systems using a analog-to-digital and digital-to-analog converter are discussed. Furthermore, methods to characterize discrete-time systems are introduced such as difference equations, $z$-transformation, and $z$-transfer function. The bilinear transformation is introduced in context of controller design.

In the second part, different control structures and design methods for linear SISO systems are discussed which go beyond the standard control loop presented in the course "systems theory and automatic control I". Concepts for feedforward control and disturbance rejection are presented and the basic structure of a cascade controller is discussed. In addition, the internal model controller, the compensation controller and the Smith predictor are treated.

In the third part of the lecture, linear multi-input multi-output (MIMO) systems are treated. The Kalman decomposition is introduced in state space as an important principle to describe the observability and controllability of a MIMO system. Controller design for directly observable systems using pole placement and LQR (Linear Quadratic Regulator) are discussed. Addressing not directly observable systems, the Luenberger observer and the Kalman filter are introduced for state estimation.

The fourth part of the lecture provides an introduction to the control of nonlinear systems. In particular, the concept of Lyapunov stability is treated and used to characterize non-linear systems.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in
• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Modulhandbuch M.Sc. Mikrosystemtechnik – Techniken zur Oberflächenmodifizierung / Surface Coating Techniques

Modul / Module

Techniken zur Oberflächenmodifizierung / Surface Coating Techniques

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5109</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / Learning target

This module describes all aspects for surface modification as often used in microsystems engineering. It tackles questions on the chemistry of the various approaches and discussion the advantages and shortcomings of a number of methods. Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings.
### Inhalte Vorlesung / Content of the lecture

Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings and techniques will be described that yield surface attached polymer monolayers and multilayer assemblies. Examples from current research topics will be discussed.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

**Technologien der Implantatfertigung / Implant Manufacturing Technologies**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5313</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Life Sciences: Biomedical Engineering
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Life Sciences: Biomedical Engineering
    - Personal Profile

### Lernziele / Learning target

Learning target and scientific objective of the module is to impart the physical and technological basics to design, develop and manufacture active implantable medical devices including basic structures and elements as well as methods and processes. The lecture lays the theoretical engineering basis to understand function and failure modes in active implantable medical devices. It teaches the students the different fundamental processes with which complex implants can be realised. The accompanying exercise complements the theoretical knowledge and adds practical aspects and guides the students to independently apply the acquired knowledge.
**Inhalte Vorlesung / Content of the lecture**

The lecture „implant manufacturing technologies“ teaches knowledge and methods to develop electrically active medical devices, e.g. cardiac pacemakers and cochlea implants. Materials, components, systems, legal requirements are covered in the lecture. Clinically established neural implants as well as latest research applications will be presented and discussed. The following topics will be covered within this course:

- Overview of active implants and neural prostheses in clinical application and research
- Definition and classification of electrical active implants
- Biocompatibility (definition and tests) and Biostability (corrosion and degradation)
- Electrodes
- Concepts of active implants (components, interfaces)
- Silicone rubber as material for encapsulation
- Materials for hermetic packages
- Assembling and packaging technologies
- Legal Requirements (risk management, FMEA, clean rooms, documentation)
- Thin-film technology and implant manufacturing
- Manufacturing of an implant on the example of a BION

The learning targets will be summarized and discussed with the students at the end of every lecture and at the end of the course to facilitate preparation of the exams.

**Inhalte Übung / Content of the exercises**

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

**Zu erbringende Prüfungsleistung / Examination result**

- Written or oral examination
- Graded exercises/practical exercises

**Benotung / Grading**

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade
of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modulhandbuch M.Sc. Mikrosystemtechnik – Technologien der Implantatfertigung – Laboratory / Implant Manufacturing Technologies - Laboratory

Modul / Module

Technologien der Implantatfertigung – Laboratory / Implant Manufacturing Technologies - Laboratory

Nummer: Number
11LE50MO-5314

Modulverantwortlicher: Responsible person
Prof. Dr. T. Stieglitz

Einrichtung: Organisational unit
Chair for Biomedical Microtechnology

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Laboratory

Sprache: Language
English

Zwingende Voraussetzungen: Mandatory preconditions
Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing technologies" in the last winter semester.

Empfohlene Voraussetzungen: Recommended preconditions
High school education in mathematics and natural sciences

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
4 Laboratory

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(56 hours Full-time attendance course of study + 34 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Objective of the module is the consolidation of the knowledge and the acquisition of skills to manufacture implants on the background of the theoretical knowledge gathered in the
The module teaches the students the application and combination of different technological processes to manufacture electrical active implantable devices under clean room conditions.

**Inhalte Praktikum / Content of the laboratory**

In the course of the practical exercises, the students re-build the first generation of a neuroprosthetic device, a cochlear implant. Groups with a maximum of three persons manufacture the implant in structured learning units on their own under supervision at different manufacturing setups. The learning units include:

- Laser marking and cutting
- Screen printing
- Hybrid implant assembly
- Design of printed circuit boards
- Development and etching of printed circuit boards
- Cleansing and cleaning of substrates
- Silicone encapsulation or electronic circuits
- Packaging and sterilization
- Technical implant function test

**Zu erbringende Prüfungsleistung / Examination result**

Written examination prior to every experiment

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Teststrukturen und Methoden für ICs and MEMS / Test Structures and Methods for ICs and MEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Microsystem Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>MEMS and IC Processing, Semiconductor Physics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (48 Hours Full-time attendance course of study + 132 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The aim of this module is to introduce the most relevant material properties, i.e., electrical, mechanical, thermal and magnetic, for materials used in MEMS to realize sensors and actuators and the respective characterization methods to extract these material properties. This theoretical part of the lecture is accomplished with a lab class where the students have to extract material properties by themselves and a seminar section, where actual publications in the field of test structures are presented by the students in 20-minute-talks.
## 19. Introduction
- 1.1 Purpose of lecture
- 1.2 Examples and background
- 1.3 Organization
- 1.4 References

## 20. Geometry
- 2.1. Film thickness
- 2.2. Lateral dimensions

## 21. Mechanical properties
- 3.1. Fundamentals
  - Stress-strain relations; Brittle vs. ductile materials; Fatigue and fracture mechanics; Parameters: Young’s modulus, shear modulus, residual stresses, coefficient of thermal expansion, fracture and yield strengths, Weibull parameters, strain hardening coefficient, creep and relaxation constants; Mechanics of beams and membranes
- 3.2. Test methods
  - Wafer curvature method; Nanoindentation; Beam bending; Resonance frequency measurements; Surface micromachined structures; Microtensile test; Membrane deflection

## 22. Magnetic properties
- 4.1. Fundamentals
  - Magnetostatics, Lorentz force and Biot-Savart law; Magnetic materials; Inductances and inductors; Magnetic forces and torques (Hall effect, Ampere’s law, stored magnetic energy and mutual inductance); Time-varying fields. Electromagnetic induction
- 4.2. Test methods

## 23. Electrical properties
- 5.1. Fundamentals
  - Electrical resistivity and contact resistance; Carrier and doping density; Carrier mobility; Carrier lifetime; Electrode impedance
- 5.2. Test methods
  - van der Pauw method; Spreading resistance measurement; Contact resistance; CV-method; Hall effect, magneto resistance; Photoconductance decay; Electrode impedance teststructures

## 24. Thermal properties
- 6.1. Fundamentals
  - Thermal conductivity; Heat capacity; Thermoelectric effect
- 6.2. Test methods
  - Macroscopic systems; MEMS based testsystems

## 25. Coupled domains properties
- 7.1. Magnetic-, mechanical-, thermal-, chemical- and radiative-magnetic
- 7.2. Electrical-, mechanical-, thermal-, chemical- and radiative-mechanical
- 7.3. Electrical-, magnetic-, thermal-, chemical- and radiative-thermal
- 7.4. Electrical-, magnetic-, mechanical-, thermal- and radiative-chemical
- 7.5. Electrical-, magnetic-, mechanical-, thermal- and chemical-electrical

## 26. Laboratory courses
- 8.1. Electrical properties
- 8.2. Mechanical properties
- 8.3. Thermal properties

## 27. Seminar presentations
Inhalte Übung / Content of the exercises

The successful completion of the exercise part of the course necessitates the preparation and delivery of a 20-minute seminar talk. Success is achieved when the talk is rated with a grade of 4 or better. The preparation of the talks by the students allows them to deal in depth with novel scientific findings in the area of the lecture. These findings have to be cast into a form that is both concise and understandable for the other participants. The person responsible for the lecture will assign topics in line with the content of the lecture.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

# Modul / Module

## Thermoelektrik / Thermoelectric

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE50MO-5715</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair for Thin-film Gas Sensors</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>German</td>
</tr>
<tr>
<td><strong>Empfohlene Voraussetzungen:</strong> Recommended preconditions</td>
<td>Basic knowledge physics, electrical engineering, microsystem technology and sensor technology</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachsemester:** Recommended term of study | 5 |
| **ECTS-Punkte:** ECTS-points | 3 |
| **SWS:** Semester week hours | 2 Lecture |
| **Angebotsfrequenz:** Regular cycle | Only in the winter term |
| **Arbeitsaufwand:** Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

## Lernziele / Learning target

Das Ziel des Moduls ist die Vermittlung der physikalischen, chemischen, elektrischen Funktionsweise thermoelektrischer Bauelemente und Systeme. Dabei werden aufbauend auf den vermittelten Grundlagen typische Materialsysteme, Modultechnologien und Anwendungen vorgestellt. Die Studierenden sollen den Zusammenhang zwischen der
Wirkungsweise, Modul- und Systemdesign, Fertigungsprozessen und dem Einsatz thermoelektrischer Systeme wie Thermogeneratoren, Peltier-Elemente und Thermocouples erlernen.

**Inhalte Vorlesung / Content of the lecture**


**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.
Verbindungshalbleiter / Compound semiconductor devices

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5111</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ambacher</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Compound Semiconductor Microsystems</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td></td>
<td>(32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

Inhalt Vorlesung / Content of the lecture

Spannende und neue physikalische Eigenschaften ergeben sich aus den immer kleiner werdenden Abmessungen von mechanischen, elektrischen und optischen Bauelementen aus Verbindungshalbleitern (GaN, GaAs, InP). In einer Einführung in die Welt der Verbindungshalbleiter-Mikrosysteme wird die Physik sowie die Technologie zur Herstellung von kleinsten Leuchtdioden und Lasern, mikromechanischen Filtern und Resonatoren sowie kleinsten Sensoren zur Analyse biologischer Prozesse vorgestellt. Neuartige Bauelemente aus Verbindungshalbleitern werden in ihrer Funktionsweise erläutert und ihre Relevanz für unser tägliches Leben dargestellt.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- Rainer Waser (Ed.) Nanoelectronics and Information Technology, Wiley-VCH Verlag GmbH & Co, 2003
## VLSI Systementwurf / VLSI System Design

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Prof. Dr. Y. Manoli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fritz-Hüttinger-Chair for Microelectronics</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulnummer: Number</td>
<td>11LE50MO-5216</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:**

2

**ECTS-Punkte:**

6

**SWS:**

2 lecture + 2 exercises

**Angebotsfrequenz:**

Only in the summer term

**Arbeitsaufwand:**

180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile

**Lernziele / Learning target**

The module is devided in lecture and practical exercise.

Lecture:

The educational objective of the lecture is to convey the methodologies in the design of digital CMOS (complementary metal-oxide semiconductor) integrated circuits. The students are able to understanding the tool chain and the underlying concepts used in computer
aided design (CAD) for microelectronic circuits and use these tools for the design of complex digital circuits. Furthermore the students learn advanced concepts in processor design. The students can use these concepts to implement a complex circuit in FPGA in the accompanying module “VLSI System Design - Laboratory”.

Practical exercise:
The educational objective of the practical exercise is that the students get practical hands-on experience with the design of digital circuits using the VHDL hardware description language. They learn all the steps from programming, testing, simulation, communication with external devices, and synthesis to an FPGA. The students learn to work within a group of 4-5 students on a multi-week project, in which they delegate subtasks and establish interface specifications between subgroups. At the end of the course, the students can use VHDL to design a digital circuit and implement this on an FPGA. They understand the basic working principles of microprocessors.

Inhalte Vorlesung / Content of the lecture

The lecture starts with a general introduction to computer aided design (CAD) for digital CMOS integrated circuits. Based on this background knowledge on the design process of digital systems, the concept of hardware description languages is introduced and VHDL as one of these languages is discussed in detail.

Fundamentals and advanced architectural components of microprocessors form another focus of the lecture. E.g. pipelining and the stack concept are discussed.

Further emphasis is put on the basics, the discussion and comparison of the algorithms (like compiled and event-driven) and scheduling for logic simulation.

The next step towards hardware in the design flow is logic synthesis which is explained from a systematic perspective. The concepts of logic minimization, factorization and technology mapping are covered in this section as well.

Another important aspect for today's VLSI circuits is design for testability. Therefore partitioning and scan-path techniques, external test, test pattern generation (D algorithm and test pattern generation for sequential circuits) and self-test are presented.

Finally - concerning the design flow - the methods of automatic layout and routing are shown in detail. Thereby the layout procedure including design system, layout editor, layout representation, fabrication steps and also layout synthesis are covered. Standard cell layout, global and local routing strategies and also layout compaction are part of this section.

The lecture closes with a discussion of low-power design principles for digital circuits and systems covering the energy-delay-product, the power dissipation of CMOS technology, and alternative related circuit technologies (silicon-on-insulator, pass-gate-logic, reduced-swing-logic, dynamic CMOS, adiabatic logic and charge-recovery-logic). Numerous aspects of power optimization approaches like leakage power reduction methodologies (power gating, multi-Vth-gates, body biasing), leakage and active power reduction by supply voltage reduction (voltage scaling, dynamic voltage scaling, sub-threshold circuits) and active power reduction methodologies (clock gating, asynchronous design) are discussed.

Inhalte Übung / Content of the exercises

In the first part, the students familiarize themselves with the VHDL hardware description language. In practical exercises, the students learn the language and the development tools (Xilinx ISE WebPack, ModelSim). Areas covered are VHDL basics, creation of test benches, and simulation.

In the second part, the students implement a small microprocessor in VHDL under supervision. This serves to further their understanding of VHDL and as the foundation for...
the final project.
In the third and major part, students are given the task to design and implement an advanced version of the microprocessor, with VGA (Monitor) and PS/2 (Keyboard) interfaces in groups of 4-5 students each. All necessary tools are supplied, such as the complete development environment and FPGA hardware board. The exact design of the processor can be freely determined by the students, as long as it conforms to the provided specification. During the course of the project, special dates are set as milestones to give the students some guidance on their progress. At each of these milestones, students also have to hand in short written reports. The last milestone is the final presentation of the project.

Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- N. Weste, D. Harris, CMOS VLSI Design: A Circuits and Systems Perspective
- J. L. Hennessy, D. A. Patterson, Computer Architecture. A Quantitative Approach
- P. Ashenden, The Designer's Guide to VHDL
- J. M. Rabaey, Digital Integrated Circuits
- R. L. Geiger, P. E. Allen, N. R. Strader, Very Large Scale Integration Design Techniques for Analogue and Digital Circuits
- W. Wolf, Modern VLSI Design: Systems on Silicon.
<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for the Chemistry and Physics of Interfaces</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

**Lernziele / Learning target**

This module describes the issues encountered at the transition from the world of Microsystems to the nanoworld. It aims at an understanding of the principle concepts for both worlds and describes current trends and problems in the field. It is also attempted to give an outlook for future research within the boundaries of physics.
Inhalte Vorlesung / Content of the lecture

1. INTRODUCTION

2. FOUNDATIONS

3. PROBLEMS
From Micro to Nano: what’s different. Physical and societal limits of nano engineering.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Bewertung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Wellenoptik / Wave optics

Nummer: 11LE50MO-5221

Modulverantwortlicher: Prof. Dr. A. Rohrbach

Einrichtung: Chair for Bio- and Nano-Photonics

Modultyp: Elective Module

Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlenes Fachsemester: 4

ECTS-Punkte: 6

SWS: 3 Lecture + 2 Übung

Angebotsfrequenz: Only in the summer term

Arbeitsaufwand: 180 hours (70 Hours Full-time attendance course of study + 110 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science inPhysik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile
- Master of Science in Physik
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / Learning target

Goal of this module is to teach the student how light interacts with small structures and how optical systems guide light. The students will start at Maxwell's equations and move on to the description of light as photon or wave, depending on the given problem. Furthermore, the close connection between spatial and temporal coherence, interference and holography is demonstrated. The last chapter teaches concepts of linear and non-linear light scattering, as well as the most important plasmonic effects. In total, the students learn how to shape light in three dimensions and how optical problems that arise in research and development
Inhalte Vorlesung / Content of the lecture

We do not really know what light is, although the concepts to describe light as waves or as particles usually work well. It is a nontrivial task to explain the colorful intensity distributions we see every day, i.e. the interactions of light with matter. Controlling light on the macroscale and the nanoscale is the key for generating impact in research, development and industry. However, this requires a thorough understanding of wave optics and its powerful theoretical instrument, the description by Fourier transforms.

This english lecture is accompanied by many live experiments and by weekly tutorials, where exercises are discussed that students have to calculate from one week to the next. The new lecture is a fusion of the two former lectures "Moderne Optik I & II" and is now organized in 6 chapters.

1. Introduction
   Some motivation, literature and a bit of history

2. From Electromagnetic Theory to Optics
   What is light? Which illustrative pictures do the Maxwell equations provide? If matter, dielectric and metallic, consists of coupled, damped springs (harmonic oscillators), how does matter depend on the frequency of light? What do the wave equation and the Helmholtz equation express and how can one handle waves in position space and frequency space.

3. Fourier-Optics
   How does a wave transforms position information into directional information? Why can this be well described by Fourier transformations in 1D, 2D and 3D? What has this to do with linear optical system theory including spatial frequency filters and the sampling theorem?

4. Wave-optical Light Propagation and Diffraction
   Different methods are introduced of how to describe the propagation of ways in position space and frequency space. We do the direct transfer from propagation to diffraction of light and momentum space. We treat evanescent waves, thin diffracted objects, the propagation of light in inhomogeneous media and the diffraction at gratings. This allows to discuss important active elements such as acousto-optic and spatial light modulators. We end with adaptive optics and phase conjugation.

5. Interference, Coherence and Holography
   We learn how a composition of k-vectors define the phases of interfering waves and the resulting stripe patterns. The relative phases of each partial wave in space and time change the interference significantly and define the coherence of light - these concepts will be discussed in detail. We learn how to write and read phase information in holography.

6. Light Scattering and Plasmonics
   The interaction of light with matter is based on particle scattering: we discuss the theoretical concepts of light scattering on the background of Fourier theory. We expend these approaches to photon diffusion, nonlinear optics, fluorescence and Raman scattering or scattering at semiconductor quantum dots - which are all hot topics in modern Photonics. A big emphasis is put on the description of surface plasmons and particle plasmons, where light can be extremely confined.

1. Introduction
### 1.1 Motivation

### 1.2 Literatur

### 1.3 A bit of history

### 2. From Electromagnetic Theory to Optics

#### 2.1 What is Light?

#### 2.2 The Maxwell-equations

#### 2.3 The change of Light in Matter

#### 2.4 Wave equation and Helmholtz equation

#### 2.5 Waves in position space and frequency space

### 3. Fourier-Optics

#### 3.1 Introduction

#### 3.2 The Fourier-Transformation

#### 3.3 Linear Optical Systems

#### 3.4 Spatial frequency filters

#### 3.5 The Sampling Theorem

### 4. Wave-optical Light Propagation and Diffraction

#### 4.1 Paraxial light propagation by Gaussian beams

#### 4.2 Wave Propagation and Diffraction

#### 4.3 Evanescent waves

#### 4.4 Diffraction at thin Phase and Amplitude Objects

#### 4.5 Light Propagation in inhomogeneous Media

#### 4.6 Diffraction at gratings

#### 4.7 Acousto Optics

#### 4.8 Spatial Light Modulators

#### 4.9 Adaptive Optics and Phase Conjugation

### 5. Interference, coherence and holography

#### 5.1 Some Basics

#### 5.2 Interferometry

#### 5.3 Foundations of Coherence Theory

### 6. Light Scattering and Plasmonics

#### 5.5 Scattering of light at particles

#### 5.6 Photon Diffusion

#### 5.7 Basics of Nonlinear Optics

#### 5.8 Fluorescence und Raman-scattering

#### 5.9 Fluorescing quantum dots

#### 5.10 Surface Plasmons and Particle Plasmons

---

### Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course achievement
The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
# Werkstoffdynamik / Dynamics of Materials

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5118</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S Hiermaier</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Sustainable Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application Field Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

## Lernziele / Learning target

Aim of the module is the knowledge of experimental and numerical basics on the mechanical behavior of materials under dynamic loading conditions. It enables the students in deriving strain-rate dependent stress-strain relations and in implementing the resulting constitutive models into numerical codes. General aim is the basic ability for experimental characterization and numerical modeling of dynamic material behavior.
### Inhalte Vorlesung / Content of the lecture

**Material Characterization:**
- Static versus dynamic material testing
- Strain-rate as measure for dynamics in materials
- Wave propagation as means of material testing
- Strain-rate-dependent elasticity, plasticity and failure
- Constitutive strain-rate dependent models
- Mathematical models for code implementation
- Shock-waves in solids
- Equations of State as component of the stress tensor
- Nonlinear Equations of State

**Numerics of Dynamic Deformation Processes:**
- Spatial and Time Discretization of dynamic deformation on solids
- Finite differences for space and time
- Finite Element Basics
- Implicit and explicit time integration
- Mesh-free Discretization

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>In addition, lecture notes will be provided</td>
</tr>
</tbody>
</table>
Modulhandbuch M.Sc. Mikrosystemtechnik – Zuverlässigkeitstechnik / Reliability Engineering

**Modul / Module**

Zuverlässigkeitstechnik / Reliability Engineering

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5214</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair for Assembly and Packaging Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Basic understanding in mathematics (statistics) as well as materials sciences

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>5</th>
</tr>
</thead>
</table>

**ECTS-Punkte: ECTS-points**

3

**SWS: Semester week hours**

<table>
<thead>
<tr>
<th>1 Lecture + 1 Übung</th>
</tr>
</thead>
</table>

**Angebotsfrequenz: Regular cycle**

Only in the winter term

**Arbeitsaufwand: Workload**

90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

**Lernziele / Learning target**

It is the aim, that after this module, the student will know:

- The student will have elementary capabilities to solve praxis-relevant.
- He/she will know how experiments can be replaced by simulation and what the
necessary input data are.

- He/she will be able to evaluate Microsystems and more complex electronic and mechatronic systems including software.
- Furthermore it is expected that the student will have improved capabilities in the risk analysis of hazardous applications.
- Also the students be able to report the corresponding results.

Inhalte Vorlesung / Content of the lecture

1. Definitions
   1.1 Quality, dependability, reliability and safety
   1.2 Benchmarks for dependability, availability und lifetime
   1.3 Statistical description of reliability
2. Dependability of mechanical systems
   2.1 Example 1: The ICE-crash at Eschede
   2.2 Loads on mechanical components
   2.3 Risk factors: notches and cracks
   2.4 Fatigue - Woehler's S-N-curve concept
   2.5 Computation of operational strength
3. Reliability of electronic hardware
   3.1 Automotive electronics: architecture, requirements and quality level
   3.2 Reliability of electronic devices, data
4. Reliability data-bases
5. Reliability of systems
   5.1 Reliability block-diagram (failure-rate analysis)
   5.2 Overview of failure mode analyses
   5.3 Fault tree analysis (FTA)
   5.4 State-Space: A general method to compute Rs(t) and Fs(t)
6. Reliability of repairable systems
   6.1 Definitions
   6.2 Repair rate
   6.3 Availability
   6.4 Markov-Chains and Markov-Processes
7. Software reliability
   7.1 Examples of software-induced accidents
   7.2 Probability of software faults
   7.3 Reliability models for software
   7.4 Misjudgements concerning software use
8. Human factors
9. Pre-requisites for development processes
10. Standards and legislation for medical devices

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benoätigung / Grading

The module grade is calculated from the result of the final examination.
Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- Short lecture notes and data files with existing ANSYS macros.