Msc. Microsystems Engineering - Introduction to the programme

Prof. Dr. Jürgen Wilde

15 October 2019
The technology
A macrosystem

The Airbus A380

- Approximately 1 Million single parts!
  - One Wing: 32,000 parts
- Costs: $ 275 Millions
  - Average per single part $ 275
- High effort for single part fabrication

Can you imagine such a system with 2 Million parts?
A microsystem

The DMD
- Digital Micro-mirror Device
- 1.6 cm x 1.6 cm
- 508,800 mirrors 17 µm x 24 µm
- ~ 2.2 million parts
- Price: ~ € 2 000
- Price / part: < 0.1 Cent
- Mass fabrications

Microsystems
- Many functions
- Small volume
Microsystems are small

Small

A hair, on the same scale. Diameter: ~ 50 µm

Smaller

Tiny
A huge variety in microsystems
Microsystems are everywhere

- **Medicine**
  - Minimally-invasive surgery
  - Diagnostics
- **Communications**
  - Fiber optics
  - Mobile phones
- **Consumer**
  - Autonomous networks
  - Sensors
- **Industry**
  - Process management
  - Instrumentation
- **Automobile**
  - Rotatio rate sensors
  - Airbags
The career
Studies: technical skills

- **Educational goal:**
  - To graduate students who can go from idea to product

- **The required skills:**
  - Problem definition
  - Solutions & evaluation

- **Design & development**
  - Fabrication
  - Characterization & optimization
  - Packaging
  - System testing & qualification
  - Transfer to production
  - Marketing

The challenge starts now
Studies: Non-technical skills

- Technical excellence is a given...

... but graduates also need:
  - Ability to work in a team
  - Social competence
  - Creativity
  - Openness to new ideas
  - Self-confidence
  - Communication skills
  - Entrepreneurial thinking
  - Ability to motivate, oneself and others
  - Leadership capabilities
Where do I go with my degree?

- **Microsystems engineers become:**
  - Entrepreneurs, technicians, engineers, group leaders, managers, CEOs, astronauts,…

- **Potential employers:**
  - Large & small companies of all types
  - Startups and spin-offs

- **What do employers want?**
  - Potential for development
  - Ability to learn
  - Communications ability (in English **and** German!)
  - Experience, experience, experience
  - Particular skills? Not so much…
The department
Faculty of Engineering

- Faculty in operation since 1995
- Department of Computer Science (IIF)
  - 19 professors / ~ 820 students
- Department of Microsystems Engineering (IMTEK)
  - 22 professors / ~ 785 students
- Department of Sustainable Systems Engineering (INATECH)
  - 7 professors / ~ 158 students
IMTEK-Professors
MEMS Applications  
Prof. Dr. Roland Zengerle

Assembly and Packaging Technology  
Prof. Dr. Jürgen Wilde

Bio- and Nano-Photonics  
Prof. Dr. Alexander Rohrbach

Biomedical Microtechnology  
Prof. Dr. Thomas Stieglitz

Biomicrotechnology  
Prof. Dr. Ulrich Egert

Chemistry and Physics of Interfaces  
Prof. Dr. Jürgen Rühe

Design of Microsystems  
Prof. Dr. Peter Woias

Electrical Instrumentation  
Prof. Dr. Leonhard Michael Reindl

Gas Sensors  
Prof. Dr. Juergen Woellenstein

Materials Process Technology  
Prof. Dr. Thomas Hanemann

Micro- and Material Mechanics  
Prof. Dr. Christoph Eberl

Microactuators  
Prof. Dr. Ulrike Wallrabe

Microelectronics  
Prof. Dr. Yiannos Manoli

Micro-optics  
Prof. Dr. Hans Zappe

Microsystems Materials  
Prof. Dr. Oliver Paul

Nanotechnology  
Prof. Dr. Margit Zacharias

Optical Systems  
Prof. Dr. Carsten Buse

Sensors  
Prof. Dr. Gerald Urban

Simulation  
Prof. Dr. Lars Pastewka

Smart Systems Integration  
Prof. Dr. Alfons Dehé

Systems Theory  
Prof. Dr. Moritz Diehl

Process Technology  
Prof. Dr. Bastian E. Rapp
Our foci in research and teaching

- Circuits and Systems
- Design and Simulation
- Biomedical engineering
- Lab-on-a-chip
- Materials
- Photonics
- Process Engineering
- Sensors and Actuators

Chip integrated fuel cell
Optical gas sensor
Electrode array for the brain
The curriculum
General principles:

- **Interdisciplinary basic education**
  in electrical engineering, physics, chemistry, materials science, technology

- **Hands-on education**
  lab classes in the clean room, electronics and chemistry lab classes, system design project...

- **Systems and application oriented education**
  with a broad, encompassing view

- **Fit for business - non-technical education**:
  project management, IP, business plans, company financing...
Structural principles of all study programs at the faculty

- 30 ECTS per semester
- 30 hours work load per credit point
- All programs are organized in modules
- A module can consist of one or several courses
- Performance evaluation after the semester
Module Components

- Lectures – German: Vorlesung (V)
- Exercises – German: Übung (Ü)
- Laboratories – German: Praktikum (Pr) oder Praktische Übung (PrÜ)

Pass/fail assessments (“Studienleistungen”)

- Exercises, reports, mid-term exams…
- Are not part of your final grade, but may be part of a module (for example the exercise sheets)
- Are not always graded (only “pass” or “fail”)

Graded assessments (“Prüfungsleistungen”)

- Written or oral exams, reports, …
- Are always graded
MSc. program in Microsystems

Scope of MSE
- Feasible in 4 semesters (average duration 6 semesters)
- 120 ECTS

Components
- Mandatory courses
- Concentrations (elective courses)
- MSc thesis

Educational goals
- Research qualification
- Laboratory techniques
- Presentation & reporting capability
## MSE – Mandatory modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Semester</th>
<th>Type</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Microsystems Engineering</strong></td>
<td>All modules to be completed</td>
<td></td>
<td><strong>53</strong></td>
</tr>
<tr>
<td>Microelectronics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Micro-mechanics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>MST Design Lab I</td>
<td>1</td>
<td>P</td>
<td>3</td>
</tr>
<tr>
<td>Micro-optics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Sensors</td>
<td>1</td>
<td>V+P</td>
<td>5</td>
</tr>
<tr>
<td>MST Technologies and Processes</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Signal Processing</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Assembly and Packaging Tech.</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Biomedical Microsystems</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Micro-actuators</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td>Micro-fluidics</td>
<td>2</td>
<td>VÜ</td>
<td>5</td>
</tr>
<tr>
<td><strong>Mathematics</strong></td>
<td>This module to be completed</td>
<td></td>
<td><strong>5</strong></td>
</tr>
<tr>
<td>Probability and Statistics</td>
<td>1</td>
<td>VÜ</td>
<td>5</td>
</tr>
</tbody>
</table>
MSE – Elective modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Semester</th>
<th>Type</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 concentration areas to be chosen. At least 9 ECTS in each of them. Total ECTS required 32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circuits and Systems</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design and Simulation</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life Sciences: Biomedical Engineering</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life Sciences: Lab-on-a-chip</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEMS Processing</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photonics</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensors and Actuators</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Profile</td>
<td>2-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's thesis (mandatory)</td>
<td>3-4</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>1-4</td>
<td></td>
<td>120</td>
</tr>
</tbody>
</table>
## MSE – Elective modules

<table>
<thead>
<tr>
<th>Circuits and systems</th>
<th>Design and Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Storage and Conversion using Fuel Cells</td>
<td>Embedded Control Laboratory</td>
</tr>
<tr>
<td>Mixed Signal CMOS Circuit Design</td>
<td>Flight Control Laboratory</td>
</tr>
<tr>
<td>Advanced embedded Systems Laboratory</td>
<td>Modelling and System Identification</td>
</tr>
<tr>
<td>Advanced Laboratory in Microcontroller</td>
<td>Numerical Optimisation</td>
</tr>
<tr>
<td>Power Electronics: Devices and Concepts</td>
<td>Numerical Optimisation Software Project</td>
</tr>
<tr>
<td>Embedded Control Project</td>
<td>Optimal Control and Estimation</td>
</tr>
<tr>
<td>Microcontroller Techniques</td>
<td>Optimal and Model Predictive Control</td>
</tr>
<tr>
<td>Power Electronic Circuits and Devices</td>
<td>Race Car Control Lab</td>
</tr>
<tr>
<td>RF- and Microwave Devices and Circuits</td>
<td>VLSI System Design</td>
</tr>
<tr>
<td>RF- and Microwave Systems Design course</td>
<td>Wind Energy Systems</td>
</tr>
<tr>
<td>Systems Theory and automatic Control II</td>
<td></td>
</tr>
<tr>
<td>Reliability Engineering</td>
<td></td>
</tr>
</tbody>
</table>
## Life Sciences: Biomedical Engg.

- Analyse von Life Science Hochdurchsatzdaten mit Galaxy
- Selected Problems in Biosignal Processing
- Biofunctional Materials - for medical microsystems and healthcare
- Biologie für Ingenieure
- Bionic Sensors - Laboratory
- Biomedical Instrumentation I
- Biomedical Instrumentation II
- Biomedical Instrumentation - Laboratory
- Biophysics of the cell
- Ethical Aspects of Neurotechnology
- Fundamentals of electrical stimulation
- Introduction to physiological Control Systems
- Implant Manufacturing Technologies
- Signal processing and analysis in brain signals
- Microsystems technology in Medicine
- Nanobiotechnology
- Neurophysiology - Laboratory
- Neuroprosthetics
- Neuroscience for Engineers

## Life Sciences: Lab-on-a-chip

- Bioactive Polymer Surfaces
- Biofuel Cells and Bioelectrochemical Systems
- BioMEMS
- Biotechnology for Engineers I: Introduction, Molecular- and Microbiology
- Biotechnology for Engineers II
- Interfaces for Bioanalytical Systems
- Introduction to data driven life sciences
- Basics in Molecular Biology for Bioanalytical Systems
- Microfluidics II: Miniaturize, automate and parallelize biochemical analysis
- Surface Analysis
## MSE – Elective modules

<table>
<thead>
<tr>
<th>Materials</th>
<th>MEMS Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioactive Polymer Surfaces</td>
<td>Lithography</td>
</tr>
<tr>
<td>Bioactive Polymer Surfaces with seminar</td>
<td>Electrochemical production technologies</td>
</tr>
<tr>
<td>Bioinspired functional materials</td>
<td>CMOS-Integrated Microsystems</td>
</tr>
<tr>
<td>Computational physics: materials science</td>
<td>Advanced Assembly and Packaging Technology</td>
</tr>
<tr>
<td>Electrochemical Energy Applications: Batteries</td>
<td>Lithography</td>
</tr>
<tr>
<td>Semiconductor Technology and Devices</td>
<td>Advanced Silicon Technology</td>
</tr>
<tr>
<td>Ceramic Materials for microsystems</td>
<td>Micro-Acoustical Transducers</td>
</tr>
<tr>
<td>Ceramic technology in microsystems</td>
<td>Microstructured Polymer Components</td>
</tr>
<tr>
<td>Physics of Failure</td>
<td>Mold Flow Simulation for Replication Processes</td>
</tr>
<tr>
<td>Contact, Adhesion, Friction</td>
<td>Nanotechnology</td>
</tr>
<tr>
<td>Continuum Mechanics I with exercises</td>
<td>Advanced Engineering</td>
</tr>
<tr>
<td>Continuum Mechanics II with exercises</td>
<td>Surface Analysis Laboratory</td>
</tr>
<tr>
<td>Mechanical Properties and Degradation Mechanisms</td>
<td>Silicon-based Neural Technology</td>
</tr>
<tr>
<td>Molecular Statics and Dynamics</td>
<td>Surface coating Techniques</td>
</tr>
<tr>
<td>Nanomaterials</td>
<td></td>
</tr>
<tr>
<td>Nano - Laboratory</td>
<td></td>
</tr>
<tr>
<td>Particle Methods in Engineering</td>
<td></td>
</tr>
<tr>
<td>Surface Analysis</td>
<td></td>
</tr>
<tr>
<td>Polymer Chemistry for Engineers</td>
<td></td>
</tr>
<tr>
<td>Polymers in Membrane Technology</td>
<td></td>
</tr>
<tr>
<td>From Microsystems to the Nanoworld</td>
<td></td>
</tr>
<tr>
<td>Dynamics of Materials</td>
<td></td>
</tr>
</tbody>
</table>
## MSE – Elective modules

<table>
<thead>
<tr>
<th>Photonics</th>
<th>Sensors and Actuators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Topics in Micro-Optics</td>
<td>Thin Film Analyses and Nanoscale Measurement Technologies</td>
</tr>
<tr>
<td>Lasers</td>
<td>Bionic Sensors</td>
</tr>
<tr>
<td>Basic Optics Lab</td>
<td>Wireless Sensor Networks</td>
</tr>
<tr>
<td>Basic and Advanced Optics Lab</td>
<td>Wireless Sensor Systems</td>
</tr>
<tr>
<td>Optical Materials</td>
<td>Disposable sensors</td>
</tr>
<tr>
<td>Optical Properties of Micro and Nano Structures</td>
<td>Electrochemical energy applications: Li-ion batteries and fuel cells</td>
</tr>
<tr>
<td>Optical Trapping and Particle Tracking</td>
<td>Energy harvesting</td>
</tr>
<tr>
<td>Optical MEMS</td>
<td>Gas Sensors</td>
</tr>
<tr>
<td>Optical Measurement Techniques</td>
<td>Power Electronics for E-Mobility</td>
</tr>
<tr>
<td>Optical Micro-Sensors</td>
<td>Electrochemical Methods for Engineers</td>
</tr>
<tr>
<td>Optoelectronics</td>
<td>Mikroaktorik für Mikrosystemtechniker</td>
</tr>
<tr>
<td>Photonic Microscopy</td>
<td>Microacoustics</td>
</tr>
<tr>
<td>Photovoltaic Energy Conversion for engineers</td>
<td>Piezoelectric and dielectric transducers</td>
</tr>
<tr>
<td>Photovoltaic Energy Conversion for engineers II</td>
<td>Quantum mechanics for engineers</td>
</tr>
<tr>
<td>Spektroskopische Methoden</td>
<td>Electronics Signal Processing for Sensors and Actuators</td>
</tr>
<tr>
<td>Wave Optics</td>
<td>Thermoelektrik</td>
</tr>
<tr>
<td></td>
<td>Compound semiconductor devices</td>
</tr>
</tbody>
</table>
# MSE courses, first semester

<table>
<thead>
<tr>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00 - 10:00 Probability and Statistics lecture Room 101 01 009/013</td>
<td>08:00-10:00 Probability and Statistics, tutorial Room 101 01 009/013</td>
<td>8:00 – 10:00 Microelectronics tutorial Room 082 00 006</td>
<td>10:00-12:00 Microelectronics lecture Room 082 00 006</td>
<td></td>
</tr>
<tr>
<td>10:00 – 12:00 Micromechanics Lecture Room 101 00 026</td>
<td>10:00-12:00 Micromechanics tutorial Room 101 01 009/013</td>
<td>10:00 - 12:00 Micro-optics lecture Room 101 00 010/014</td>
<td>12:00 - 14:00 MST Design Lab I Room 082 00 006</td>
<td></td>
</tr>
<tr>
<td>13:00 – 14:00 MST Technologies and Processes, tutorial Room 101 00 026</td>
<td>13:00 - 14:00 Sensors Lecture Room 101 01-009/013</td>
<td>14:00 – 16:00 MST Technologies and Processes, lecture Room 101 00 026</td>
<td>14:00 – 16:00 Micro-optics tutorial Room 051 00 034 Room 051 00 006</td>
<td></td>
</tr>
<tr>
<td>14:00 – 16:00 Sensors Lecture Room 101 01-009/013</td>
<td>14:00 – 16:00 MST Technologies and Processes, lecture Room 101 00 026</td>
<td>16:00 – 18:00 Sensors Lab, group 1 Room 078 00 035</td>
<td>16:00 – 18:00 Sensors Lab, group 4 Room 078 00 035</td>
<td></td>
</tr>
<tr>
<td>16:00 – 18:00 MST Design Lab I Lecture Room 082 00 006</td>
<td>16:00 – 18:00 Sensors Lab, group 1 Room 078 00 035</td>
<td>18:00 – 20:00 Sensors Lab, group 2 Room 078 00 035</td>
<td>18:00 – 20:00 Sensors Lab, group 2 Room 078 00 035</td>
<td></td>
</tr>
</tbody>
</table>
Plagiarism

- Plagiarism is:
  - Using someone else’s texts, pictures, reports, data, solutions, whatever….
  - ... without giving the source

- Sources include:
  - Books, the internet, colleagues, …

- To make it clear:
  - Plagiarism is illegal

- The simple „if...then“ loops:
  - If you plagiarize...(once)
  - … then you fail
  - If you plagiarize repeatedly (=twice)
  - … then your academic career is over.
Some thoughts to share…

- **A Master’s program in Germany**
  - You have to organize your courses and your life
  - Make sure to observe the deadlines for course and exam registration
  - We challenge you from the first day on to assess given knowledge…
  - …and to transfer given knowledge from one course to another
  - We will show you many aspects of microsystems related disciplines and applications to broaden your knowledge and increase the opportunities for an exciting career.

- **That means for you…**
  - YOU have to take the initiative to ASK, ASK and read until you understand
  - WE give you the overview, YOU have to learn the details
The art of living

Enjoy being a student!
- It is helpful to
- Structure your day
- Have unstructured free time
- Meet colleagues
- Keep up with your work
- Turn off on occasion

Don’t forget
- Family
- Friends
- Sports
- Culture
- Autumn leaves…
Moreover…

- Buy textbooks
- Contact your mentor
- Form study groups
- Poke around in the laboratories
- Find an MSc thesis advisor early
- Stay registered
- Get enough sleep
  - But not in my class, please
Mentoring

- Every student has a faculty mentor
  - A professor as a contact person
  - Assigned by the Dean of Studies
- Student’s contact for:
  - Problems, questions, clarifications, job searches, recommendations, or just general advising
After graduation
Apply for a job

- **In Industry**
  - Find out what you like during your MSc program
  - Use job portals and company websites to monitor the market
  - Visit career workshops to gather tips how to apply
  - Go to recruiting fairs
Phd. as research assistant

- Perform a research project (on your own)
- Look for an open position
- Apply
- Get paid for the PhD project
- Overtake responsibility as project assistant
- Support your professor with respect to educational tasks
- Duration: 3-5 years
Contact persons I

- **Dean of studies:** Prof. Moritz Diehl
  - Moritz.diehl@imtek.de
  - 203 67852

- **Program coordinator:** Ursula Epe
  - studienkoordination@tf.uni-freiburg.de
  - 203 8340

- **Student advisers:**
  - studienberatung@imtek.de
    - Dr. Andreas Greiner
      - 203 67479
    - Dr. Oswald Prucker
      - 203 7164
Contact persons II

- Examination office
  - Anne-Julchen Müller
    - pruefungsamt@tf.uni-freiburg.de
    - 203 8083
  - Susanne Storck
    - pruefungsamt@tf.uni-freiburg.de
    - 203 8083
International Admissions and Services (IAS) and Central Academic Advising (ZSB) at Service Center Studium is your first resort for all information and advice concerning your studies at Sedanstr. 6 (b/n library and theatre)
Information

Clearing / first information

- Where to go to …?
- Whom to talk to if…?
- How do I…?
- daily info desk

Hotline
0761 / 203-4246

Advising

...on any topic concerning your studies

- confidential
- impartial
- professional
- open and scheduled consultation hours

Workshops

Smalls groups (mostly in German), topics such as:

- Doubts / hard choices
- Dealing with (study) stress
- Time and self-management
- Masters degree or job search?

www.zsb.uni-freiburg.de www.ias.uni-freiburg.de
Thank you very much for your attention!