Module Descriptions

Master of Science Advanced Materials

Absorption: Nanomaterials

Examination Regulations in the Version of: 2017
## Elective Courses I

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<tr>
<td>Compound Semiconductors</td>
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## Elective Courses II

### Elective Courses II - Chemistry

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<td>Exploring the Nanoworld with X-Rays and High-Energy Electrons</td>
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<td>Micro- and Nanotechnology</td>
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<td>Advanced Laboratory Materials and Engineering Science</td>
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<td>Thin Films Laboratory</td>
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<td>Principles of Structure Formation in Nanomaterials</td>
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<td>Semiconductor Sensors</td>
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<td>Thin Films</td>
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### Elective Courses II - Physics

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<td>Laboratory Principles of Scanning Electron Microscopy</td>
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Additive Key Qualifications 93
Additive Key Qualifications 95
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Master Thesis

Master’s Thesis 100
# Advanced Materials Science

Modules referring to Elective Courses I

<table>
<thead>
<tr>
<th>Code</th>
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<tr>
<td>Language of instruction</td>
<td>English</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Summer Semester</td>
</tr>
</tbody>
</table>

**Coordinator**

Prof. Dr. U. Herr, Faculty of Engineering, Computer Science

**Instructor(s)**

Prof. Dr. U. Herr, Faculty of Engineering, Computer Science

**Allocation of study programmes**

MSc Advanced Materials, semester 2, Nanomaterials

**Recommended prerequisites**

Fundamentals of mathematics, physics and chemistry

**Learning objectives**

Advanced Materials Science (Materials Science II)

Students should be able to

- interpret the influence of the processing of a metallic alloy, ceramic and polymeric substance on its microstructure and properties.
- relate the structure of a composite material to the improved strength and toughness.
- select appropriate materials and processing routes for the realization of an engineering design goal, based on properties and performance characteristics.

**Syllabus**

- Application of basic concepts introduced in part 1 of the lecture to different classes of materials: Metallic alloys, ceramics, glasses, polymers.
- Processing/optimization of materials, heat treatment
- Electrical properties of materials
- Semiconductors
- Magnetic properties of materials
- Optical properties of materials
<table>
<thead>
<tr>
<th>Literature</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture 3 h/week</td>
<td>Exercise 1 h/week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Total 150 h</td>
<td></td>
</tr>
<tr>
<td>Lecture:</td>
<td></td>
</tr>
<tr>
<td>42 h presence</td>
<td>50 h preparation and revision</td>
</tr>
<tr>
<td>Solving problems:</td>
<td></td>
</tr>
<tr>
<td>14 h presence</td>
<td>28 h revision, solution of exercises</td>
</tr>
<tr>
<td>Exam: 16 h preparation</td>
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</tbody>
</table>

| Assessment                                                             | The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration. |

| Grading procedure                                                      | The grade of the module will be the grade of the exam.                                                                                                                                              |

| Basis for                                                              | Research in field of Materials structure, Nanomaterials                                                                                                                                              |
Compound Semiconductors
Modules referring to Elective Courses I

Code 8822874162

ECTS credits 5

Attendance time 3

Language of instruction English

Duration 1 Semester

Cycle each Summer Semester

Coordinator Prof. Dr. F. Scholz, Faculty of Engineering, Computer Science and Psychology

Instructor(s) Prof. Dr. F. Scholz, Faculty of Engineering, Computer Science and Psychology

Allocation of study programmes MSc Advanced Materials, semester 2, Nanomaterials

Recommended prerequisites Fundamentals of semiconductor physics

Learning objectives After successfully having finished the module, the students are able to describe the basic physics of compound semiconductors and contrast them to those of elemental semiconductors. They are able to describe important characteristics like band gap, lattice constant and refractive index and identify their systematic trends. From those basics, they are able to derive the application possibilities of compound semiconductors and discuss their advantages and disadvantages. They are able to describe and compare the most important fabrication and characterization methods. They are able to describe the constitution of the most important basic hetero structures and explain their mode of operation. Based on that, they are able to develop the structure of important representative devices like light emitting diodes or laser diodes and to describe in detail the function of the respective structural details.

Syllabus
- Basics of Semiconductors, Compound Semiconductors
- Bulk crystal growth, liquid phase epitaxy, vapor phase epitaxy, molecular beam epitaxy
- Optical processes, spectroscopic methods
- Electrical characterization methods
- x-ray diffraction, microscopy methods, other characterization methods
- Strain in semiconductor structures
- Low-dimensional structures: quantum wells, wires, dots
- Semiconductor Light emitters and Laser Diodes
- Short Wavelength materials: Group III nitrides
- Electronic devices: HEMTs, HBTs
- Solar Cells

**Literature**
- skript to lecture
- O. Madelung, Grundlagen der Halbleiterphysik, Springer
- S.M. Sze, Physics of Semiconductor Devices, John Wiley
- E. Rosencher, B. Vinter, Optoelectronics, Cambridge University Press 2002
- K.J. Ebeling; Integrated optoelectronics : waveguide optics, photonics, semiconductors
  Berlin ; Heidelberg [u.a.] : Springer, 1993

**Teaching and learning methods**
- Lecture 3h/week
- Exercise 1h/week

**Workload**
- Total: 150 h
- Lecture: 60 h
  - 30 h preparation and revision
- Exercise: 15 h
  - 30 h preparation and revision
- Exam: 15 h revision

**Assessment**
The grade of the module will be the grade of the oral exam. No prerequisites are necessary for exam registration.

**Grading procedure**
The grade of the module will be the grade of the exam.

**Basis for**
MSc Advanced Materials, Nanomaterials
Characterization Techniques for Fuel Cells and Batteries
Modules referring to Elective Courses II - Chemistry

Code 8822872049

ECTS credits 3

Attendance time 2

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Head of the ZSW respective Head of the HIU

Instructor(s) Dr. Roswitha Zeis

Allocation of study programmes
Master Chemistry, Study Program Chemistry, elective or specialization (Energy Technology), 1.-3. Semester
Master Chemistry and Management, specialization / Module Group 2 (Energy Technology), 1.-3. semester
Master Energy Science and Technology, elective, 1.-3. semester
Master Advanced Materials, elective, 1.-3. semester

Recommended prerequisites
Formal prerequisites (according to Study order and examination regulations): none

Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

Learning objectives
Student should be able to

# describe and explain diagnostics employed in the characterization and determination of Proton Exchange Membrane (PEM) fuel cells and battery performance.

# gain a more precise understanding of the physical and chemical processes that occur in PEM fuel cells and batteries based on knowledge of these diagnostic tools.

# start working on a master thesis in the field of electrochemical energy converters and storage devices.
Syllabus

This module provides the following content:
1. In situ cell tests
   # Steady state voltage-current measurements
   # Polarisation and charge-discharge curves
   # Impedance spectroscopy
   # Neutron scattering
   # Synchrotron radiation

2. Evaluation of cell components (Membranes, Separators, Electrolytes, Electrodes, Catalysts, Gas Diffusion Layers ...)
   # Structural analysis (SEM, TEM, XRD, microtomography, porosity determination)
   # Elemental analysis (XRF, ICP-MS, EDX)
   # Electrochemical surface area (BET, cyclic volammery)
   # Catalytic activity (Rotating Ring Disk Electrode)
   # Membrane degradation (Neutron scattering, Fenton test)

Literature

- Handouts

Teaching and learning methods

Lecture (2 hours per week, 3 CP)

Workload

Presence: 30 h
Self Study: 60 h
Total: 90 h

Assessment

The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration

Grading procedure

The grade of the module will be the grade of the exam.

Basis for

Research in field of Fuel cells and Batteries
# Colloid Chemistry

Modules referring to Elective Courses II - Chemistry

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<tr>
<th>Code</th>
<th>8822871307</th>
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<tbody>
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<td>Language of instruction</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Cycle</td>
<td>each Summer Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. Ulrich Ziener</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. Ulrich Ziener</td>
</tr>
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**Allocation of study programmes**
- Master Chemistry, Study Program Chemistry, elective or specialization (Macromolecular Chemistry), 1.-3. semester
- Master Chemistry, Study Program Materials, elective, 1.-3. semester
- Master Chemistry and Management, specialization / Module Group 2 (Macromolecular Chemistry), 1.-3. semester
- Master Advanced Materials, elective, 1.-3. semester

**Recommended prerequisites**
- **Formal prerequisites (according to Study order and examination regulations):** none
- **Prerequisites regarding to the contents:** Bachelor’s competences in the field related to the subject

**Learning objectives**
- Students who have successfully completed this module
  - know the essential details of the synthesis and characterization of (polymeric) colloids

**Syllabus**
- This module provides the following content:
  - history of colloid chemistry
  - stabilization of colloids
  - surface-active agents
  - applications of surface-active agents
Literature
- Dörfler: Grenzflächen- und Kolloidchemie, Wiley-VCH

Teaching and learning methods
Lecture (2 hours per week)

Workload
Presence: 30 h
Private study: 60 h
Total: 90 h

Assessment
The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.

Grading procedure
The grade of the module will be the grade of the exam.

Basis for
Research in the field of chemistry, polymers and Colloids
### Functional Properties of Nanomaterials

**Modules referring to Elective Courses II - Chemistry**

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<td>Language of instruction</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>PD Dr. Joachim Bansmann</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>PD Dr. Joachim Bansmann</td>
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</tbody>
</table>

**Allocation of study programmes**
- Master Chemistry, Study Program Materials, elective, 1.-3. semester
- Master Advanced Materials, elective, 1.-3. semester

**Recommended prerequisites**
- Formal prerequisites (according to Study order and examination regulations): none
- **Prerequisites regarding to the contents**: Bachelor’s competences in the field related to the subject

**Learning objectives**
The students who have finished this module successfully have knowledge and understanding
- about topical technologies for the production and characterisation of different Nanostructures
- of the physical properties of Nanostructures, based on their spatial construction structure (electronic, optical and magnetic qualities)

**Syllabus**
In this module the following contents are given:
- Introduction to the Nanoscience under consideration of the state of the technology
- Analytic possibilities in the Nanoscience: STM/STS, AEM, SEM, TEM
- Production and qualities of Nanostructures: "Top-Down" methods and new materials; "Bottom-Up" methods
- Electronic and optical qualities
- Magnetic qualities

<table>
<thead>
<tr>
<th>Literature</th>
<th>Handouts; are made available in the lecture</th>
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<td>Lecture (2 hours per week, 3 CP)</td>
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<tr>
<td>Workload</td>
<td>Presence study: 30 H</td>
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<tr>
<td></td>
<td>Selfstudy: 60 H</td>
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<td></td>
<td>Sum: 90 H</td>
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<td>Grading procedure</td>
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</tr>
<tr>
<td>Basis for</td>
<td>Research in Nanomaterials</td>
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## Hydrogen as Energy Carrier

Modules referring to Elective Courses II - Chemistry

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<td><strong>Language of instruction</strong></td>
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</tr>
<tr>
<td><strong>Duration</strong></td>
<td>1 Semester</td>
</tr>
<tr>
<td><strong>Cycle</strong></td>
<td>each Winter Semester</td>
</tr>
<tr>
<td><strong>Coordinator</strong></td>
<td>PD Dr. Christian Mohrdieck</td>
</tr>
<tr>
<td><strong>Instructor(s)</strong></td>
<td>PD Dr. Christian Mohrdieck</td>
</tr>
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</table>

### Allocation of study programmes

- Master Chemistry, Study Programm Chemistry, elective or specialization (Energy Technology), 1.-3. semester
- Master Chemistry and Management, specialization / Module Group 2 (Energy Technology), 1.-3. semester
- Master Energy Science and Technology, elective, 1.-3. semester
- Master Advanced Materials, elective, 1.-3. semester

### Recommended prerequisites

**Formal prerequisites (according to Study order and examination regulations):** none

**Prerequisites regarding to the contents:** Bachelor's competences in the field related to the subject

### Learning objectives

- Students who have successfully completed this module
- are familiar with the scientific, technical and economic aspects of hydrogen as a promising and environmentally friendly energy source
- have an idea of technical applications

### Syllabus

This module provides the following content:

- Overview hydrogen in research and applications
- Production methods, logistics and infrastructure for hydrogen
- Hydrogen storage methods (non-compressed gaseous)
- Storage methods (compressed hydrogen gas)
- Hydrogen (re)fueling technology
- Process, stationary and alternative applications
- Application of hydrogen in transportation, fuel cell vehicles
- Hydrogen - Fuel Cell - Efficiency - Entropy
- Visit of hydrogen and fuel cell laboratory, witnessing a leakage test
- Visit of a hydrogen refueling station and fuel cell vehicle test drive
- Different pathways of hydrogen production and use. Comparison with other energy sources based on the complete energy chain efficiency and emissions
- Tool for the visualization of energy chain efficiency results
- Safety, regulations, codes and standards
- Future perspectives of hydrogen as an energy carrier

**Literature**

- Zuttel, Andreas; Borgschulte, Andreas; Schlapbach, Louis (eds.): Hydrogen as a future energy carrier (Wiley-VCH, Weinheim, 1. Auflage 2008)
- International seminar proceedings, 3rd (Springer Netherlands, 2003)

**Teaching and learning methods**

Lecture (2 hours per week)

**Workload**

Presence: 30 h  
Private study: 60 h  
Total: 90 h

**Assessment**

The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration

**Grading procedure**

The grade of the module will be the grade of the exam.

**Basis for**

Research in field of Energy and Energy conversion
Lithium Ion Batteries
Modules referring to Elective Courses II - Chemistry

Code 8822871323

ECTS credits 3

Attendance time 2

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Head of the ZSW or Head of the HIU

Instructor(s) Dr. Margret Wohlfahrt-Mehrens

Allocation of study programmes
- Master Chemisty, Study Programm Chemistry, elective or specialization (Energy Technology), 1.-3. semester
- Master Chemistry and Management, specialization / Module Group 2 (Energy Technology), 1.-3. semester
- Master Energy Science and Technology, elective, 1.-3. semester
- Master Advanced Materials, elective, 1.-3. semester

Recommended prerequisites
- Formal prerequisites (according to Study order and examination regulations): none
- Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

Learning objectives
- Students who have successfully completed this module, - are familiar with the basics of lithium-ion batteries
- know the correlations between binary and ternary phase diagrams and electrochemistry
- have distinctive knowledge of structure and property relationships in compounds

Syllabus
- This module provides the following content:
  - Electrochemical energy storage systems
  - Introduction to Lithium batteries
  - Basic principles I
  - Cathode materials I
- Cathode materials II
- Nanomaterials
- Measurement techniques
- Anode materials I
- Anode materials II
- Electrolytes
- Electrode/Electrolyte interface (SEI)
- Battery management I
- Battery management II
- Alternative Systems, Lab visit ZSW

Literature
- M. Whittingham, Intercalation compounds, in fast ion transport, Dordrecht (1993)

Teaching and learning methods
Lecture (2 hours per week)

Workload
Presence: 30 h
Private study: 60 h
Total: 90 h

Assessment
The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration

Grading procedure
The grade of the module will be the grade of the exam.

Basis for research in the field of Batteries
# Advanced Laboratory Chemistry

Modules referring to Elective Courses II - Chemistry

<table>
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<tr>
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<td>Language of instruction</td>
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<td>Duration</td>
<td>2 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. K.E. Gottschalk</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Lecturers of the chemistry</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>Master Advanced Materials, elective module, semester 2 or 3</td>
</tr>
</tbody>
</table>

### Recommended prerequisites

**Formal prerequisites (according to Study order and examination regulations):** none

**Prerequisites regarding to the contents:** Bachelor’s competences in the field related to the subject

### Learning objectives

The students who have finished this module successfully,
- earn the skill and competence to work independently on a project in theory and practice in a selected field of chemistry, write it down, discuss it academically in a short treatise, and present it clearly.

### Syllabus

In this module the following contents are given:

**Practical research project on a topical subject in selected areas of chemistry from the working groups**

### Literature

- it is made available
- independent literature search
<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Project work (lab course) Chemistry with written elaboration and presentation in the working group or institute</th>
</tr>
</thead>
</table>
| Workload                      | Attendance: 180 h  
|                               | preparation & report: 60 h  
|                               | Total: 240 h                                                              |
| Assessment                    | The award of the credit points for this module is based on completion of an assignment (presentation and paper), active participation in discussions and practical skills. No prerequisites are necessary for exam registration. |
| Grading procedure             | The grade of the module will be the grade of the exam |
| Basis for                     | Research in selected field |
Polymeric Materials
Modules referring to Elective Courses II - Chemistry

Code 8822871305

ECTS credits 3

Attendance time 2

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Prof. Dr. Ulrich Ziener

Instructor(s) Prof. Dr. Ulrich Ziener

Allocation of study programmes
- Master Chemistry, Study Program Chemistr, compulsory module (Macromolecular Chemistry), 1.-3. semester
- Master Chemistry, Study Program Materials, compulsory module, 1.-3. semester
- Master Chemistry and Management, specialization / Module Group 2 (Macromolecular Chemistry), 1.-3. semester
- Master Advanced Materials, elective, 1.-3. semester

Recommended prerequisites
Formal prerequisites (according to Study order and examination regulations): none

Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

Learning objectives
Students who have successfully completed this module,
- are able to understand and describe modern applications of organic and macromolecular materials

Syllabus
This module provides the following content:
- Block copolymers for the synthesis of nanoparticles
- Conductive polymers
- Liquid crystalline polymers
- Nanostructuring
- Porous polymeric materials
- Thermoreversible gels
<table>
<thead>
<tr>
<th>Literature</th>
<th>Scientific articles in professional journals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching and</td>
<td>Lecture (2 hours per week)</td>
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<tr>
<td>learning methods</td>
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<td>Workload</td>
<td>Presence: 30 h</td>
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<td></td>
<td>the oral or written (depending on the number</td>
</tr>
<tr>
<td></td>
<td>of participants) exam. No prerequisites are</td>
</tr>
<tr>
<td></td>
<td>necessary for exam registration</td>
</tr>
<tr>
<td>Grading procedure</td>
<td>The grade of the module will be the grade of</td>
</tr>
<tr>
<td></td>
<td>the exam.</td>
</tr>
<tr>
<td>Basis for</td>
<td>If Macromolecular Chemistry is chosen as the</td>
</tr>
<tr>
<td></td>
<td>&quot;Fourth Subject&quot;, it is obligatory to pass</td>
</tr>
<tr>
<td></td>
<td>Polymeric Materials (to complete the respective module group).</td>
</tr>
</tbody>
</table>
Simulation and Modeling
Modules referring to Elective Courses II - Chemistry

Code: 8822873964
ECTS credits: 5
Attendance time: keine Angaben
Language of instruction: English
Duration: 1 Semester
Cycle: each Winter Semester
Coordinator: Prof. Dr. A. Latz, Faculty of Natural Sciences, Helmholtz Institute Ulm
Instructor(s): Prof. Dr. A. Latz, Faculty of Natural Sciences, Helmholtz Institute Ulm

Allocation of study programmes: Third Semester MSc Advanced Materials, Nanomaterials

Recommended prerequisites:

Learning objectives: Student will be able to

• understand the basic theoretical concepts of electrochemistry, non-equilibrium thermodynamics and chemical kinetics
• distinguish between the modeling approaches for different length and time scales
• perform discretization of transport equations using Finite difference, Finite Volume and Finite Element Techniques
• solve numerically ordinary and partial differential equations using standard software tools
• describe mathematically the operation of batteries and fuel cells

Syllabus:

• Transport theory
• Thermodynamics and chemical kinetics of electrochemical systems
• Introduction to simulation techniques
• Discretization of transport equations and kinetic equations
• Fundamentals of systems theory
• Modelling of Batteries
• Modelling of fuel cells
• Software exercises
Literature


Teaching and learning methods

Lecture, 2 h/week
Solving problems, 2 h/week

Workload

Total: 150 h
Lecture: 32 h presence
50 h revision
Solving problems: 32 h presence
36 h preparation and revision

Assessment

The credit points will be awarded once the written exam has been passed. No prerequisites are necessary for exam registration.

Grading procedure

The grade of the module will be the grade of the exam.

Basis for

Master thesis
Surface - Interfaces - Heterogeneous Catalysis - Electrocatalysis

Modules referring to Elective Courses II - Chemistry

Code: 8822873965

ECTS credits: 5

Attendance time: keine Angaben

Language of instruction: English

Duration: 1 Semester Semester

Cycle: each Summer Semester

Coordinator: Prof. Dr. R. J. Behm, Faculty of Natural Sciences

Instructor(s): Prof. Dr. R. J. Behm, Faculty of Natural Sciences

Allocation of study programmes: Second semester MSc Energy Science and Technology and MSc Advanced Materials

Recommended prerequisites: Module Chemistry I

Learning objectives: Students should be able to

- describe basic aspects of solid surfaces and their properties (structure, electronic properties) as well as their interaction with adsorbates;
- describe basic principles of heterogeneous catalysis and catalytic reactions, and apply them to model reactions (CO oxidation and ammonia synthesis);
- explain fundamental principles of electrochemistry, including solid electrolyte interface, potentials, electrode kinetics, transport effects, basic electrochemical measurements;
- describe basic principles, energetics and kinetics of electrocatalytic reactions, focusing on fuel cell relevant reactions, and predict simple trends for suitable catalysts

Syllabus:

- Surfaces: Phenomenologic thermodynamics of surfaces, surface structure and electronic properties of solid surfaces, interaction of molecules with surfaces (thermodynamics, kinetics and energetics);
- Catalytic Surface Reaction (Heterogeneous Catalysis): Fundamental aspects, methodical approach, basic reaction types, activity, selectivity, electronic and structural effects, Sabatier principle, Brønstedt-Evans-Polanyi principle, model reactions (CO oxidation, ammonia synthesis);
- Electrochemistry: Galvanic cells, potentials in electrochemistry, standard electrode potential, electrochemical double layer, electrode kinetics, transport effects, experimental methods;
- Electrocatalysis: General aspects, influence of the electric potential on energetics and kinetics of electrocatalytic reactions, kinetic / transport limitations in electrocatalytic reactions, internal resistance effects, examples of electrocatalytic reactions, temperature effects.

**Literature**


**Teaching and learning methods**

5 credit points  
Lecture 3h/week  
Seminar 1h/week

**Workload**

- Total 150 h  
- 56 h lecture and seminar (presence)  
- 78 h preparation and revision of lecture and seminar and solving of problems  
- 16 h preparation for exam

**Assessment**

The credit points will be awarded once the oral exam has been passed. No prerequisites are necessary for exam registration.

**Grading procedure**

The grade of the module will be the grade of the exam.

**Basis for**

Module *Energy Science and Technology III-Electrochemical EST*  
Research in field of *Energy and storage materials*  
Elective Course *Polymeric Materials*
Advanced Materials Science
Modules referring to Elective Courses II - Materials and Engineering Science

Code 8822874161
ECTS credits 5
Attendance time 3
Language of instruction English
Duration 1 Semester
Cycle each Summer Semester
Coordinator Prof. Dr. U. Herr, Faculty of Engineering, Computer Science
Instructor(s) Prof. Dr. U. Herr, Faculty of Engineering, Computer Science

Allocation of study programmes MSc Advanced Materials, semester 2, Nanomaterials

Recommended prerequisites Fundamentals of mathematics, physics and chemistry

Learning objectives Advanced Materials Science (Materials Science II)
Students should be able to
- interpret the influence of the processing of a metallic alloy, ceramic and polymeric substance on its microstructure and properties.
- relate the structure of a composite material to the improved strength and toughness.
- select appropriate materials and processing routes for the realization of an engineering design goal, based on properties and performance characteristics.

Syllabus
- Application of basic concepts introduced in part 1 of the lecture to different classes of materials: Metallic alloys, ceramics, glasses, polymers.
- Processing/optimization of materials, heat treatment
- Electrical properties of materials
- Semiconductors
- Magnetic properties of materials
- Optical properties of materials

| **Teaching and learning methods** | Lecture 3 h/week  
Exercise 1 h/week |

| **Workload** | Total 150 h |
| Lecture: | 42 h presence  
50 h preparation and revision |
| Solving problems: | 14 h presence  
28 h revision, solution of exercises |
| Exam: | 16 h preparation |

| **Assessment** | The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration. |

| **Grading procedure** | The grade of the module will be the grade of the exam. |

| **Basis for** | Research in field of Materials structure, Nanomaterials |
# Computational Methods in Materials Science

Modules referring to Elective Courses II - Materials and Engineering Science

<table>
<thead>
<tr>
<th><strong>Code</strong></th>
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<td><strong>Attendance time</strong></td>
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<tr>
<td><strong>Language of instruction</strong></td>
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</tr>
<tr>
<td><strong>Duration</strong></td>
<td>1 Semester</td>
</tr>
<tr>
<td><strong>Cycle</strong></td>
<td>each Winter Semester</td>
</tr>
<tr>
<td><strong>Coordinator</strong></td>
<td>Prof. Dr.-Ing. Ulrich Herr</td>
</tr>
</tbody>
</table>
| **Instructor(s)** | Prof. Dr.-Ing. Ulrich Herr  
| | Prof. Carl Krill, Ph.D.  
| | Dr. Ulrich Simon |

**Allocation of study programmes**

**Recommended prerequisites**
- recommended: Materials Science I and II

**Learning objectives**
Students should be able to recognize the interplay between length/time scales and the computational methods used for simulation in materials science. They can describe the theoretical underpinnings of the finite element method, the phase field method, molecular dynamics and the Monte Carlo method. They are able to explain the strengths and limitations of each of these simulation methods based on practical experience acquired during computer lab exercises. Finally, they can select an appropriate simulation method for solving a given materials science problem computationally.

**Syllabus**
- Introduction  
- Modeling in materials science  
- Numerical solution of differential equations  
- Finite element method (FEM)  
- Introduction and fundamentals  
- Linear variational functions  
- Applications in one dimension
– General finite element approach
– Examples
Phase field method
– Introduction
– Allen-Cahn model
– Energy functional
– Numerical solution methods
– Application to grain growth
Molecular dynamics
– Introduction: statistical mechanics
– Interatomic potentials
– Equations of motion, integration
– Correlation functions
– Examples
Monte Carlo methods
– Introduction
– Metropolis Monte Carlo algorithm
– Ising model
– Resident time algorithm, diffusion

Literature
- S. E. Koonin, D. C. Meredith: Computational Physics (Addison-Wesley, 1990)
- D. C. Rapaport: The Art of Molecular Dynamics Simulation (Cambridge, 2004)

Teaching and learning methods
Lecture “Computational Methods in Materials Science”, 2 SWS
Laboratory “Computational Methods in Materials Science”, 1 SWS

Workload
lecture + computer lab (presence): 45 h
preparation and revision of lecture notes, lab reports: 55 h
exam preparation: 20 h
Total: 120 h

Assessment
The grade of the module will be the grade of the written exam. Prerequisite for exam registration is passing the pre-course (to be defined by the examiner). Exam 120 min. duration.

Grading procedure
The grade of the module will be the grade of the exam.

Basis for
-
Compound Semiconductors
Modules referring to Elective Courses II - Materials and Engineering Science

<table>
<thead>
<tr>
<th>Code</th>
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<tbody>
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<td>ECTS credits</td>
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<tr>
<td>Language of instruction</td>
<td>English</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Summer Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. F. Scholz, Faculty of Engineering, Computer Science and Psychology</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. F. Scholz, Faculty of Engineering, Computer Science and Psychology</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>MSc Advanced Materials, semester 2, Nanomaterials</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>Fundamentals of semiconductor physics</td>
</tr>
</tbody>
</table>

**Learning objectives**

After successfully having finished the module, the students are able to describe the basic physics of compound semiconductors and contrast them to those of elemental semiconductors. They are able to describe important characteristics like band gap, lattice constant and refractive index and identify their systematic trends. From those basics, they are able to derive the application possibilities of compound semiconductors and discuss their advantages and disadvantages. They are able to describe and compare the most important fabrication and characterization methods. They are able to describe the constitution of the most important basic hetero structures and explain their mode of operation. Based on that, they are able to develop the structure of important representative devices like light emitting diodes or laser diodes and to describe in detail the function of the respective structural details.

**Syllabus**

- Basics of Semiconductors, Compound Semiconductors
- Bulk crystal growth, liquid phase epitaxy, vapor phase epitaxy, molecular beam epitaxy
- Optical processes, spectroscopic methods
- Electrical characterization methods
- x-ray diffraction, microscopy methods, other characterization methods
- Strain in semiconductor structures
- Low-dimensional structures: quantum wells, wires, dots
Semiconductor Light emitters and Laser Diodes
Short Wavelength materials: Group III nitrides
Electronic devices: HEMTs, HBTs
Solar Cells

Literature
- skript to lecture
- O. Madelung, Grundlagen der Halbleiterphysik, Springer
and Practices, Vol. 7: III-V-Semiconductor Materials and Devices, North-
Holland, Amsterdam, Oxford, New York, Tokyo 1989
- D.T.J. Hurle (ed.), Handbook of Crystal Growth, North-Holland, Amsterdam
1993, Vol. 1-3
- S.M. Sze, Physics of Semiconductor Devices, John Wiley
- R.K. Willardson, A.C. Beer, Semiconductors and Semi-metals, Book Series
Academic
Press; g. Vol. 22, Vol. 24
- E. Rosencher, B. Vinter, Optoelectronics, Cambridge University Press 2002
- K.J. Ebeling: Integrated optoelectronics : waveguide optics, photonics,
semiconductors
Berlin ; Heidelberg [u.a.] : Springer, 1993

Teaching and learning methods
Lecture 3h/week
Exercise 1h/week

Workload
Total: 150 h
Lecture: 60 h
30 h preparation and revision
Excercise: 15 h
30 h preparation and revision
Exam: 15 h revision

Assessment
The grade of the module will be the grade of the oral exam. No prerequisites are
necessary for exam registration.

Grading procedure
The grade of the module will be the grade of the exam.

Basis for
MSc Advanced Materials, Nanomaterials
Exploring the Nanoworld with X-Rays and High-Energy Electrons
Modules referring to Elective Courses II - Materials and Engineering Science

**Code** 8822870904

**ECTS credits** 3

**Attendance time** 2

**Language of instruction** English

**Duration** 1 Semester

**Cycle** each Winter Semester

**Coordinator** Prof. Dr. Ute Kaiser

**Instructor(s)** Prof. Dr. Ute Kaiser, Prof. Ph. D. Carl Emil Krill, Prof. Dr.-Ing. Ulrich Herr

**Allocation of study programmes** Master Advanced Materials, elective module, semester 3

**Recommended prerequisites** Materials Science I, Materials Science II

**Learning objectives** Selected topics of research and methods in Nanophysics and Nanoengineering

**Syllabus**
- Scattering of x-rays and electrons
  - elastic scattering
  - background info: biographies of Röntgen, Bragg/Bragg, Ruska
  - application: Ewald sphere-x-ray diffraction vs. TEM
- Inelastic scattering of x-rays and electrons
  - theory of absorption, - applications: EBSD
- Diffraction from crystals-Bragg peak intensities
  - structure factor
  - intensity analysis (Rietveld)
- indexing complex powder diffraction patterns
- application: macromolecular crystallography
- Diffraction from crystals-Bragg peak shapes
- peak shape analysis (Fourier methods)
- size/strain separation (Warren-Averbach)
- application: characterization of nanocrystalline materials
X-ray reflectometry
- Fresnel equation
- effect of interface roughness
- methods for simulation
- application: analysis of thin-film thickness, multilayers

Magnetic lenses and lens aberrations
- magnetic focusing of electrons
- sources of lens aberrations
- application: CS-corrector

High-resolution TEM
- phase and amplitude contrast
- contrast transfer function
- application: multislice simulation,

Atomic-resolution Z-contrast
- Z-contrast, STEM, TEM
- application: atomic-resolution imaging, EELS, energy-filtered TE

Holography
- amplitude vs. phase information
- light holography
- electron holography
- application: magnetic microstructure of bacteria

Lorentz microscopy
- magnetic contrast
- imaging conditions
- application: magnetic "ripple" in thin films, Abrikosov lattice

Electron tomography (Bright-field, Z-contrast)
- imaging (Z-contrast, Amplitude Contrast)
- principles of image reconstruction, visualization
- application: materials science
- application life science

X-ray tomography
- sources of contrast (absorption, phase, diffraction, fluorescence)
- reconstruction artefacts
- applications: CT of human bone under mechanical loading, metallic foams

X-ray microscopy
- x-ray lenses (Fresnel, refraction)
- concepts for 3-D resolution
- application: growth of individual grains during recrystallization

Focused ion beam
- ion irradiation
- imaging with ion beam
- single vs. dual-beam units
- application: sample preparation, lithography, electron tomography

Small-angle x-ray scattering (SAXS)
- theory
- measurement apparatus
- application: nanoparticle growth, ferrofluid characterization

Literature
Selected literature for preparing the presentations, handouts
<table>
<thead>
<tr>
<th><strong>Teaching and learning methods</strong></th>
<th>Exploring the Nanoworld (S), 1 h/week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workload</strong></td>
<td>28 h lecture (presence)</td>
</tr>
<tr>
<td></td>
<td>52 h preparation of presentation and revision seminar</td>
</tr>
<tr>
<td></td>
<td>10 h seminar (presence) an presentation</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>90 h</strong></td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>not specified</td>
</tr>
<tr>
<td><strong>Grading procedure</strong></td>
<td>not specified</td>
</tr>
<tr>
<td><strong>Basis for</strong></td>
<td>MSc Advanced Materials</td>
</tr>
</tbody>
</table>
# Micro- and Nanotechnology

Modules referring to Elective Courses II - Materials and Engineering Science

<table>
<thead>
<tr>
<th>Code</th>
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<tbody>
<tr>
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<td>Language of instruction</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. Peter Unger</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. Peter Unger</td>
</tr>
</tbody>
</table>

**Allocation of study programmes**

Advanced Materials (Nanomaterials) MSc, begin of study WiSe, compulsory modul, 3. semester

**Recommended prerequisites**

Introductory Engineering

**Learning objectives**

This course on the Micro- and Nanotechnology provides an advanced understanding of the technology for fabricating structures with micron- and nanometer-scale dimensions.

**Syllabus**

At the beginning of the course, the basic technological processes for lithography and pattern transfer techniques are discussed. As applications of these technologies, fabrication processes are presented like CMOS and III-V technology, micromechanics, magnetic thin-film heads, flat-panel displays, micro optics, x-ray optics and quantum-effect electronic devices. The lectures are accompanied by exercises, where important original publications will be discussed and hands-on experiments in the clean room will be performed.

**Literature**


| Teaching and learning methods | Micro- and Nanotechnology (L), 2 h/week  
|                              | Micro- and Nanotechnology (E), 1 h/week |
| Workload                     | 28 h lecture (presence)  
|                              | 14 h exercises, practical training (presence)  
|                              | 34 h preparation and postprocessing lecture  
|                              | 28 h solution of exercises, postprocessing  
|                              | 16 h exam preparation                                  |
| Total: 120 h                  |                                            |

| Assessment                   | examination of 120 min., precondition: successful participation in exercises |
| Grading procedure            | Exam result                                                      |
| Basis for                    | MSc Advanced Materials                                           |
## Advanced Laboratory Materials and Engineering Science

#### Modules referring to Elective Courses II - Materials and Engineering Science

<table>
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<tr>
<th>Code</th>
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<tbody>
<tr>
<td>ECTS credits</td>
<td>8</td>
</tr>
<tr>
<td>Attendance time</td>
<td>keine Angaben</td>
</tr>
<tr>
<td>Language of instruction</td>
<td>English</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. K.-E. Gottschalk, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Lecturers of Faculty of Natural Sciences and Faculty of Engineering, Computer Science and Psychology</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>Master Advanced Materials, elective courses, semester 2or 3</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>Formal prerequisites (according to Study order and examination regulations): none</td>
</tr>
<tr>
<td></td>
<td>Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject</td>
</tr>
<tr>
<td>Learning objectives</td>
<td>The students who have finished this module successfully, - earn the skill and competence to work independently on a project in theory and practice in a selected field of Materials or Engineering Science, write it down, discuss it academically in a short treatise, and present it clearly.</td>
</tr>
<tr>
<td>Syllabus</td>
<td>In this module the following contents are given: Practical research project on a topical subject in selected areas of Material or Engineering Science from the working groups</td>
</tr>
<tr>
<td>Literature</td>
<td>- it is made available</td>
</tr>
<tr>
<td></td>
<td>- independent literature search</td>
</tr>
<tr>
<td><strong>Teaching and learning methods</strong></td>
<td>Project work (lab course) with written elaboration and presentation in the working group or institute</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| **Workload**                     | Attendance: 180 h  
preparation & report: 60 h  
Total: 240 h                                                                                      |
| **Assessment**                   | The award of the credit points for this module is based on completion of an assignment (presentation and paper), active participation in discussions and practical skills. No prerequisites are necessary for exam registration. |
| **Grading procedure**            | The grade of the module will be the grade of the exam.                                           |
| **Basis for**                    | Research in selected field                                                                       |
Thin Films Laboratory
Modules referring to Elective Courses II - Materials and Engineering Science

Code 8822873966

ECTS credits 3

Attendance time keine Angaben

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Dean of Studies, Faculty of Natural Sciences

Instructor(s) Prof. Dr. U. Herr; Faculty of Computer Science, Engineering and Psychology

Allocation of study programmes MSc Advanced Materials, semester 3

Recommended prerequisites module Thin films or comparable knowledge

Learning objectives Students should be able to
- perform lab work fabrication and characterization of thin films
- operate modern equipment for determination of important film parameters such as thickness, composition, mechanical and magnetic properties.
- apply modern magneto-resistive sensors for magnetic field measurement.

Syllabus
1 Thin Film Growth
2 X-ray Reflectivity (XRR) on Thin Films
3 X-ray Photoelectron Spectroscopy (XPS) on Thin Films
4 Magneto-optical Kerr effect (MOKE) and Kerr Microscopy
5 Giant Magneto-Resistance (GMR) based Spin Valve sensors

Literature
<table>
<thead>
<tr>
<th><strong>Teaching and learning methods</strong></th>
<th>lab experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workload</strong></td>
<td>Laboratory 60 h</td>
</tr>
<tr>
<td></td>
<td>preparation of report: 30 h</td>
</tr>
<tr>
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<td>Total: 90h</td>
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<tr>
<td><strong>Assessment</strong></td>
<td>The credit points will be awarded once the written exam has been passed. No prerequisites are necessary for exam registration.</td>
</tr>
<tr>
<td><strong>Grading procedure</strong></td>
<td>The module is not graded.</td>
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<tr>
<td><strong>Basis for</strong></td>
<td>Research in the field of Materials Science</td>
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</tbody>
</table>
# Principles of Structure Formation in Nanomaterials

Modules referring to Elective Courses II - Materials and Engineering Science

<table>
<thead>
<tr>
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<td>Language of instruction</td>
<td>English</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Cycle</td>
<td>keine Angaben</td>
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<tr>
<td>Coordinator</td>
<td>Prof. Dr. R. J. Behm, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Lecturer, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>MSc Advanced Materials, Electives, semester 3</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>Modules semester 1 and 2, Nanomaterials</td>
</tr>
</tbody>
</table>

## Learning objectives

Students should be able to

- analyze physical and chemical surface properties of complex systems
- apply the fundamental knowledge of processes on surfaces to other systems
- discuss the kinetics of reactions on surfaces in model systems
- describe the basics of electrochemistry at surfaces
- discuss the physics and chemistry of small clusters (gas phase)

## Syllabus

1. Surface structuring and nanoparticles:
   - Classes of chemical reactions/processes
   - Growth modes in growth processes
   - Elementary surface processes during film growth

2. Applications of nanoparticles:
   - Usage in heterogeneous catalysis
   - Basic types of bimolecular catalytic reactions

3. Cluster based materials:
   - Chemisorption (dissociative/molecular) and molecular physisorption
   - Cluster structure calculations based on the Lennard-Jones (LJ) interaction
   - Potential, cluster mass spectra
- Carbon cluster structures
- One-dimensional metal structures

<table>
<thead>
<tr>
<th>Literature</th>
<th>to be announced in lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching and learning methods</td>
<td>Lecture 2 h/week</td>
</tr>
<tr>
<td>Workload</td>
<td>Total 90 h</td>
</tr>
<tr>
<td></td>
<td>32 h presence</td>
</tr>
<tr>
<td></td>
<td>58 h preparation and post-processing</td>
</tr>
<tr>
<td>Assessment</td>
<td>The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.</td>
</tr>
<tr>
<td>Grading procedure</td>
<td>The grade of the module will be the grade of the exam.</td>
</tr>
<tr>
<td>Basis for</td>
<td>MSc Advanced Materials, Nanomaterials</td>
</tr>
</tbody>
</table>
Semiconductor Sensors
Modules referring to Elective Courses II - Materials and Engineering Science

Code 8822870450

ECTS credits 5

Attendance time 3

Language of instruction English

Duration 1 Semester

Cycle each Summer Semester

Coordinator Prof. Dr.-Ing. Hermann Schumacher

Instructor(s) Dr. Alberto Pasquarelli

Allocation of study programmes
- Electrical Engineering, M.Sc., Elective Module
- Electrical Engineering, M.Sc., Compulsory Subject Module, Microelectronics
- Electrical Engineering, M.Sc., Optional Module, Automation and Energy Technology
- Communications Technology, M.Sc., Optional Technical Module, Microelectronics
- Embedded Systems, M.Sc., Application Subject, Mixed Signal Systems

Recommended prerequisites Halbleiterbauelemente

Learning objectives The advances in microelectronics and micro electro-mechanical systems (MEMS) have revolutionized the scenario of sensor technology. Thanks to new materials and processes, traditional bulky, slow and expensive sensor systems could be replaced by miniaturized and integrated smart sensors based on semiconductors. With the help of semiconductor sensors various application areas have been developed. In everyday life we encounter them, for example, in the form of navigation and control systems in vehicles or as microphones, accelerometers, compass and cameras in mobile phones and tablets. In addition to the automotive industry and the mobile communications, semiconductor sensors are used in many other areas, for example, in health care to record the blood pressure or body temperature in real time.

The students describe and classify principles of operation, technological implementations and application areas of different sensors. They recognize and discuss the various physical phenomena in semiconductors, which are used for the detection of physical quantities and their conversion to electrical signals. They know various semiconductor materials suitable for the production of sensors, analyze the peculiarities of each one, explain and predict their response under different conditions and can calculate sensor examples for different measurement needs. The students can design a semiconductor sensor choosing the right
material among several semiconductors. They are able to analyze a measurement problem, compare appropriate sensing techniques and develop their own solution. Doing this they can properly dimension the sensor unit to meet the design specifications.

<table>
<thead>
<tr>
<th>Syllabus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiconductor-based detection methods for:</td>
</tr>
<tr>
<td>- radiation (ionizing and non-ionizing)</td>
</tr>
<tr>
<td>- magnetic fields</td>
</tr>
<tr>
<td>- mechanical forces</td>
</tr>
<tr>
<td>- temperature</td>
</tr>
<tr>
<td>Basics on operational amplifiers</td>
</tr>
<tr>
<td>Basics on MST (micro system technology)</td>
</tr>
<tr>
<td>Basics on MEMS (micro electro-mechanical systems)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture Notes</td>
</tr>
<tr>
<td>For in-depth study, following books (University library) are recommended:</td>
</tr>
<tr>
<td>Pierret: Field effect devices - TK 7871.95/1990 P</td>
</tr>
<tr>
<td>Michalski: Temperature measurement - I: QC 291/1991 M</td>
</tr>
<tr>
<td>Glück: MEMS in der Mikrosystemtechnik - T99: TK 7875/2005 G</td>
</tr>
<tr>
<td>Hilleringmann: Mikrosystemtechnik - T99: TK 7875/2006 H</td>
</tr>
<tr>
<td>Middelhoek: Silicon sensors - I: T 50/1989 M</td>
</tr>
<tr>
<td>Sze: Semiconductor sensors - T99: T 50/1994 Sc</td>
</tr>
<tr>
<td>Fraden, Jacob - Handbook of modern sensors – I: T 50/1993 F</td>
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<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
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<tbody>
<tr>
<td>Lecture “Semiconductor Sensors”, 3 SWS</td>
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<tr>
<td>Exercise “Semiconductor Sensors”, 1 SWS</td>
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<table>
<thead>
<tr>
<th>Workload</th>
</tr>
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<tbody>
<tr>
<td>Active Time: 45 h</td>
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<tr>
<td>Preparation and Evaluation: 105 h</td>
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<tr>
<td>Sum: 150 h</td>
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<table>
<thead>
<tr>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>The grade of the module will be the grade of the written exam. No prerequisites are necessary for exam registration</td>
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</table>

<table>
<thead>
<tr>
<th>Grading procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>The grade of the module will be the grade of the exam.</td>
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</table>

<table>
<thead>
<tr>
<th>Basis for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master thesis in the area of semiconductor sensors.</td>
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### Thin Films

Modules referring to Elective Courses II - Materials and Engineering Science

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<th>Code</th>
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<td>ECTS credits</td>
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<td>Duration</td>
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<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. Ulrich Herr</td>
</tr>
</tbody>
</table>

#### Instructor(s)

Prof. Dr. Ulrich Herr

### Allocation of study programmes

Master degree in Advanced Materials, elective, 3. semester

### Recommended prerequisites

Materials Science I, Materials Science II

### Learning objectives

Understanding of thin film technology and processing techniques. Critical assessment of property changes in thin films with respect to bulk materials. Understand microstructure/property relationships in thin films.

### Syllabus

1. Vacuum science and technology
   - Kinetic gas theory, application
   - Vacuum pumps and measurement
2. Thin film growth techniques
   - Evaporation
   - Sputtering
3. Substrate surface and nucleation
   - Thermodynamics and kinetics of nucleation and growth
4. Epitaxy
   - Lattice misfit and defects
   - Mechanisms and characterization
5. Film structure
- Structural morphology
- Grain growth, texture, microstructure control
- Amorphous thin films
6. Mechanical properties of thin films
- Internal stresses: origin and analysis
- Mechanical relaxation effects
7. Magnetic properties of thin films
- Micromagnetism
- Magnetic structures in thin films
8. Applications
- Magnetic recording media
- Magneto-electronics

**Literature**

**Teaching and learning methods**
Thin Films (L) 2 h/week, (E) 1 h/week

**Workload**
- 28 h lecture (presence)
- 32 h preparation and revision lecture
- 14 h exercises (presence)
- 16 h exam preparation

**Total**: 90 h

**Assessment**
The credit points will be awarded once the written exam has been passed. No prerequisites are necessary for exam registration.

**Grading procedure**
The grade of the module will be the grade of the exam.

**Basis for**
MSc course of studies Advanced Materials
**Basics of Scanning Electron Microscopy**
Modules referring to Elective Courses II - Physics

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<td>Duration</td>
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<td>Cycle</td>
<td>each Summer Semester</td>
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<tr>
<td>Coordinator</td>
<td>Dean of Physics Studies</td>
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<tr>
<td>Instructor(s)</td>
<td>Prof. Ute Kaiser</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>Master Advanced Materials, elective module, 2nd Semester</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>None</td>
</tr>
</tbody>
</table>
| Learning objectives | Students who have successfully completed this module,  
• are able to describe the function of basic components of a scanning electron microscope,  
• are able to understand basic SEM modes: imaging, diffraction and spectroscopy. |
| Syllabus | In this module, the following topics will be covered:  
• Components of the SEM  
• Physical phenomena of electron-matter interaction |
<p>| Literature | Will be announced in lecture. |</p>
<table>
<thead>
<tr>
<th><strong>Teaching and learning methods</strong></th>
<th>Lecture (2 hours per week)</th>
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<tr>
<td><strong>Workload</strong></td>
<td>30 hours lecture (attendance time)</td>
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<td></td>
<td>30 hours self-study and exam preparation</td>
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<td>Total: 60 hours</td>
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<td><strong>Grading procedure</strong></td>
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<td><strong>Basis for</strong></td>
<td>Research in the field of Electron Microscopy</td>
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</table>
Experimental Quantum Optics
Modules referring to Elective Courses II - Physics

Code 8822872190
ECTS credits 6
Attendance time 6
Language of instruction English
Duration 1 Semester
Cycle each Winter Semester
Coordinator Dean of Physics Studies
Instructor(s) Prof. Alexander Kubanek

Allocation of study programmes
- Physics M.Sc., elective module, 1st or 2nd semester
- Wirtschaftsphysik M.Sc., elective module, 1st - 3rd semester
- Advanced Materials M.Sc., compulsory elective module, 1st - 3rd semester

Recommended prerequisites Optics, Atomic Physics, Quantum Mechanics

Learning objectives Students who successfully pass this module
- are familiar with concepts and techniques used in modern Quantum Optics
- know the application of Laser Physics and the applications of lasers for cavity QED

Syllabus
- Laser Physics
- Quantum nature of light
- Interaction of light and matter
- Atomic and "atom-like" systems
- Cavity Quantum Electrodynamics
- Current research topics in Quantum Optics (Nonlinear Optics, Quantum Entanglement, Bell's inequalities, Quantum Teleportation, Quantum Cryptography, Quantum Computing)

Literature Specific literature will be provided throughout the course. In-depth literature research is also part of independent preparation of the student presentations.
Quantum Optics books for general preparation:

- G. Grynberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
- M. O. Scully and M. S. Zubairy, Quantum Optics (Cambridge University Press, Cambridge, 1997)

More specialized books:

- C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg, Atom-Photon Interactions (Wiley-Interscience); comment: specialized on Light Atom Interaction
- S. Haroche, J. M. Raimond, Exploring the Quantum, (Oxford University Press 2006); comment: specialized on cavity QED

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Lecture (3 hours per week)</th>
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<tbody>
<tr>
<td></td>
<td>Exercise (2 hours per week)</td>
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<table>
<thead>
<tr>
<th>Workload</th>
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<tbody>
<tr>
<td>45 hours lecture (attendance time)</td>
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<tr>
<td>30 hours exercise (attendance time)</td>
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<tr>
<td>105 hours self-study and exam preparation</td>
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<tr>
<td>Total: 180 hours</td>
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<table>
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<th>Assessment</th>
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<tr>
<td>The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. Prerequisite for exam registration is passing the pre-course (to be defined by the examiner).</td>
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<table>
<thead>
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<table>
<thead>
<tr>
<th>Basis for</th>
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<tbody>
<tr>
<td>Research in the fields of Quantum Information and Technologies</td>
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Crystal Defects: Physical Effects and Mechanics  
Modules referring to Elective Courses II - Physics

Code 8822872189

ECTS credits 3

Attendance time 2

Language of instruction English

Duration 1 Semester

Cycle irregular

Coordinator Dean of Physics studies

Instructor(s) Prof. Jeong-Ha You, Max Planck Institute for Plasma Physics, Garching

Allocation of study programmes Physics M.Sc., elective module, 1st or 2nd semester  
Advanced Materials M.Sc., compulsory elective module, 1.-3. semester

Recommended prerequisites Introductory courses in calculus, mechanics and solid state physics

Learning objectives Students who successfully pass this module  
• gain basic understanding on the types, structures, formation mechanisms and physical effects of various kind of crystal defects  
• are equipped with theoretical skills for describing the dynamic interactions and energetic reactions between defects based on a continuum mechanics framework  
• are able to interpret various physical, thermal and mechanical features being observed in actual crystalline solids in terms of defect effects in addition to idealized bulk behaviours  
• gain fundamental knowledge on the microstructures and mechanical behaviours of engineering materials

Syllabus  
• Classification and structures of crystal defects  
• Point defects: formation mechanisms, physical effects, thermodynamics, irradiation damage  
• Elements of solid mechanics (linear elastic), continuum slip theory, crystal plasticity  
• Line defects: edge/screw dislocation, slip mechanisms, stress/displacement/strain fields
- Dynamics of dislocation: line tension, forces between dislocations, reaction mechanisms
- Planar defects: structure of grain boundaries, impact on mechanical behaviour, interactions
- Recovery of defects, recrystallization and grain growth

**Literature**
- Mechanical Behaviour of Materials, Keith Bowman, John Wiley & Sons, 2004
- Physikalische Grundlagen der Materialkunde, G. Gottstein, Springer-Lehrbuch (3 Aufl.), Springer
- Introduction to Dislocations, Hull & Bacon, Pergamon (3rd Ed.)
- Theory of Dislocations, Hirth & Lothe, John Wiley & Sons
- Crystal Defects and Microstructures, R. Phillips, Cambridge University Press
- Mechanical Metallurgy, M. Meyers, K. Chawla, Prentice Hall

**Teaching and learning methods**
- Course type: block lecture
- For example: Monday-Thursday, 12:30-18:00

**Workload**
- 22 hours lecture (attendance time)
- 23 hours exercise (attendance time)
- 45 hours self-study and exam preparation
- Total: 90 hours

**Assessment**
- The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.

**Grading procedure**
- The grade of the module will be the grade of the exam.

**Basis for**
- Research in the field of Condensed Matter
Micro- and Nanostructured Optics
Modules referring to Elective Courses II - Physics

Code 8822870626

ECTS credits 2

Attendance time 1

Language of instruction English

Duration 1 Semester

Cycle irregular

Coordinator Prof. Dr. Robert Brunner

Instructor(s) Prof. Dr. Robert Brunner

Allocation of study programmes Master degree in Advanced Materials, elective, 3. semester

Recommended prerequisites Introductory Solid State Physics, Materials Science I and II

Learning objectives The shrinking of optical dimensions down to the micro- and nanometer scale is opening new approaches to design and to realize optical devices and systems with divers and other fascinating opportunities. The application spectrum ranges from consumer optics, e.g. micro-mirror devices for projection displays, up to sophisticated, high performance systems in deep-UV lithography or in space science. Learned lessons from nature, and also the introduction of new bottom-up structuring techniques, are meanwhile shifting optical feature sizes down to the nanometer range. The goals of the course are to present a selection of topics in micro- and nanooptics, to develop and expand an intuitive understanding of the application potentials in this field, and to understand the technological challenges.

Syllabus

• refractive and diffractive microoptics
• fabrication techniques: e.g. e-beam-, laser-, interference lithography
• replication processes
micro opto electro mechanical systems (MOEMS)
hybrid optics
nanostructured optics
moth-eye effect
near field optics

**Literature**
Lukas Novotny and Bert Hecht, Principles of Nano-Optics, Cambridge
Handouts

**Teaching and learning methods**
Micro- and nanostructured Optics(L), 1 h/week

**Workload**
14 h lecture (presence)
30 h preparation and revision lecture
16 h exam preparation
**Total: 60 h**

**Assessment**
The credit points will be awarded once the written or oral exam has been passed (depending on the number of participants). The type of examination will be announced in time - at least 4 weeks prior to the date of the exam. No prerequisites are necessary for exam registration.

**Grading procedure**
The grade of the module will be the grade of the exam.

**Basis for**
Research in this field of studies
Nearfield Optics and Plasmonics
Modules referring to Elective Courses II - Physics

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<tr>
<td>Duration</td>
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<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
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<tr>
<td>Coordinator</td>
<td>Prof. Othmar Marti</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Dr. Manuel Rodrigues Gonçalves</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>Physics M.Sc., elective module, 1st or 2nd Semester</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>Electromagnetic Waves: properties and mathematical description, Optics, Fundamentals of algebra and mathematical analysis are required.</td>
</tr>
<tr>
<td>Learning objectives</td>
<td>Near-field optics (NFO) includes all optical phenomena at nanoscale dimensions. Plasmonics is closely related to NFO and is the domain of physical effects related to and generated by surface-plasmons, i.e. quantized oscillations of electrons coupled with electromagnetic waves. For particles larger than a few nm, the theory of surface-plasmons is mainly based on the Maxwell's equations. Plasmonic particles are actually a subject of increasing research because of the unprecedented strong light focusing at the nanoscale, field enhancements and extraordinary optical sensitivity. Modern microscopy techniques, including scanning near-field optical microscopy (SNOM), reach resolutions much smaller than the wavelength and require a good knowledge of the optical phenomena at the nanoscale. In this course, fundamental principles of near-field optics and plasmonics are introduced. Examples and functionality of SNOM and confocal microscopes are presented in detail. Plasmonic nanostructures and their optical properties are discussed. Fabrication techniques, simulation methods and applications will be presented in detail. Some experiments will be carried out during the semester. Students can learn to operate some optical microscopes, to fabricate nanostructures and to characterize them using other techniques.</td>
</tr>
</tbody>
</table>
Students who successfully passed this module

- understand the mathematical description of electromagnetic waves in near- and far-field
- know the physical basis of surface plasmons and the preparation of plasmonic nanostructures
- can operate optical scanning near-field microscopes
- can simulate optical properties of nanoparticles

**Syllabus**

- Concepts of near-fields and far-fields
- Principles of confocal and SNOM microscopy
- SNOM probes and near-fields probing methods
- Fresnel formulas
- Light scattering, absorption and extinction of isolated nanoparticles
- Mie theory
- Plasmons in films and nanoparticles
- Fabrication techniques of noble metal nanostructures
- Simulation of optical properties of plasmonic particles
- Surfaces-enhanced Raman scattering
- Near-field enhancement and fluorescence
- Optical forces and thermal effects of plasmons
- Quantum plasmonics

**Lab experiments:**

- Fabrication of plasmonic nanostructures
- Confocal microscopy: reflection and transmission modes
- SNOM in illumination/transmission mode
- Angle-resolved spectroscopy
- Light scattering and surface-plasmon resonance
- Surface enhanced Raman scattering

**Literature**

- Nanoplasmonics, V. Klimov, Pan Stanford Publishing 2014
- Modern Introduction to Surface Plasmons, D. Sarid and W. Challener, Cambridge 2010
- Journal papers and lectures script

**Teaching and learning methods**

Lecture with practical course 2 h/week

**Workload**

30 h lecture with practical course (attendance time)

60 hours self-study and examination preparation

Total: 90 hours

**Assessment**

The credit points will be awarded once the written or oral exam has been passed (depending on the number of participants). The type of examination will be announced in time - at least 4 weeks prior to the date of the exam. No prerequisites are necessary for exam registration.
<table>
<thead>
<tr>
<th><strong>Grading procedure</strong></th>
<th>The grade of the module will be the grade of the exam.</th>
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</thead>
<tbody>
<tr>
<td><strong>Basis for</strong></td>
<td>Research in field of Near field optics and plasmonic</td>
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</tbody>
</table>
NMR Spectroscopy and Imaging Methods
Modules referring to Elective Courses II - Physics

Code 8812872557

ECTS credits 6

Attendance time 6

Language of instruction English

Duration 1 Semester

Cycle one-time

Coordinator Dean of Physics Studies

Instructor(s) Prof. Dr. Volker Rasche, Prof. Dr. Fedor Jelezko

Allocation of study programmes Physics M.Sc., elective module, 1\textsuperscript{st} or 2\textsuperscript{nd} semester

Wirtschaftsphysik M.Sc., elective module, 1\textsuperscript{st} - 3\textsuperscript{rd} semester

Recommended prerequisites None

Learning objectives Students who successfully pass this module:

- know the basic concepts of imaging techniques in medicine and various system architectures
- understand the application of various imaging methods
- understand the fundamentals of magnetic resonance spectroscopy
- are able to handle a magnetic resonance tomography

Syllabus Imaging methods

The lecture deals with the basic principles of imaging techniques currently used in medicine. Imaging techniques in medicine allow for generating image-based information about the anatomy and function of the human body. The methods involved are based on different physical principles such as:

- X-rays (X-classical and computer based tomography (CT)),
- Nuclear Magnetic Resonance imaging (MRI),
- Ultrasound (ultrasound and echocardiography),
- Positron Emission Tomography (PET),
- Single Photon Emission Computed Tomography (SPECT).
The lecture will be divided into four blocks. Each block deals with different physical principles and relative system architectures, advantages and disadvantages of the methods involved, as well as their main fields of application in medicine.

**Physical principles of magnetic resonance spectroscopy**

- Introduction to NMR: QM description of spins, spin operators, density matrix
- Semi-classical description, Bloch equations
- Lineshape of NMR signal
- Spin echoes
- Theory of relaxation: coherence times (T2 and T1), extreme narrowing regime, intensity of NMR signal
- Electronic shielding, chemical shift
- Spin-Spin coupling, J coupling
- Dipolar interactions, averaging by molecular motion
- Magic angle spinning
- Polarization transfer in NMR: nuclear Overhauser effect, Solomon equations, Hartmann-Hahn resonance, solid effect, optical hyperpolarization
- Two dimensional NMR, COSY experiment
- New detection methods for NMR: Magnetic resonance force microscopy (MRFM), NV centres in diamond

**Literature**

- Arnulf Oppelt (Ed), Imaging Systems for Medical Diagnostics, (2005), ISBN: 3895782262

**Teaching and learning methods**

- Imaging methods in medical technology (lecture, 2 hours per week)
- Physical principles of NMR (lecture and exercise, 2 hours per week)
- Practical course (3 hours per week)
- Project work

**Workload**

- 45 hours lecture (attendance time)
- 15 hours exercise (attendance time)
- 45 hours practical course
- 30 hours project work
- 45 hours self-study
- Total: 180 hours

**Assessment**

The module will be passed once the project has been passed. Prerequisite for exam registration is passing the pre-course (to be defined by the examiner)

**Grading procedure**

The grade of the module will be the grade of the exam.
Basis for Research in Condensed Matter and/or Biophysics
Physics of Scattering
Modules referring to Elective Courses II - Physics

Code 8822873469

ECTS credits 2

Attendance time 1

Language of instruction English

Duration 1 Semester

Cycle each academic Year

Coordinator Dean of Physics Studies

Instructor(s) Dr. Masoud Amirkhani

Allocation of study programmes Advanced Materials M.Sc., elective module, 1st or 2nd Semester

Recommended prerequisites -

Learning objectives Students who successfully passed this module
  • have broadened their knowledge in special experimental techniques
  • understand how to prepare samples for the different experimental methods
  • know the limits of the different techniques and be able to estimate their
    advantages and disadvantages

Syllabus
  • Fundamentals of scattering theory
  • Scattering equation for a dispersion of spherical colloid particles
  • Experimental methods (small angle neutron scattering (SANS), small angle
    X-ray scattering, static and dynamic light scattering), their advantages and
    disadvantages and their limits
  • Experimental techniques for different kind of samples

Literature
  • Methods of X-ray and Neutron Scattering in Polymer Science Ryong-Joon Roe
  • Small angle x-ray scattering, O. Glatter, O. Kratky
  • Dynamic light scattering: with applications to chemistry, biology, and physics By
    Bruce J. Berne, Robert Pecora
<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Lecture (1 hour per week)</th>
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<tbody>
<tr>
<td></td>
<td>Exercise (1 hour per week)</td>
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<table>
<thead>
<tr>
<th>Workload</th>
<th>15 hours Lecture (attendance time)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>15 hours Exercise (attendance time)</td>
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<tr>
<td></td>
<td>30 hours self-study and examination preparation</td>
</tr>
<tr>
<td></td>
<td>Total: 60 hours</td>
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| Assessment                    | The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration. |

| Grading procedure             | The grade of the module will be the grade of the exam. |

| Basis for                     | Research in field of scattering |
### Advanced Laboratory Physics

**Modules referring to Elective Courses II - Physics**

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<td><strong>Attendance time</strong></td>
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<td><strong>Language of instruction</strong></td>
<td>English or German</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>1 Semester</td>
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<tr>
<td><strong>Cycle</strong></td>
<td>each Semester</td>
</tr>
<tr>
<td><strong>Coordinator</strong></td>
<td>Prof. Othmar Marti</td>
</tr>
<tr>
<td><strong>Instructor(s)</strong></td>
<td>Prof. Othmar Marti, Dr. Manuel Goncalves</td>
</tr>
</tbody>
</table>

**Allocation of study programmes**

Advanced Materials M.Sc., elective module, semester 2 or 3

**Recommended prerequisites**

**Formal prerequisites (according to Study order and examination regulations):** none

**Prerequisites regarding to the contents:** Bachelor's competences in the field related to the subject

**Learning objectives**

Students who successfully passed this module

- understand modern measurement techniques and are able to handle complex measuring equipment,
- have the ability to make measurements and to analyse the data of advanced physical experiments,
- are able to set-up, run and evaluate complex experiments as well as report the results in a clear manner.

**Syllabus**

- Modern microscopic methods
- Solid state physics
- Semiconductor physics
- Nuclear physics
- Scattering and diffraction techniques
- Optical spectroscopy
- Biophysics
- Soft matter physics
- Fundamentals of advanced metrology
Literature

Lab manual

Teaching and learning methods

Lab work with two-days experiments (8 hours per week)

Workload

120 hours laboratory course (attendance time)
120 hours self-study, data evaluation, report writing
Total: 240 hours

Assessment

The award of the credit points for this module is based on completion of an assignment (presentation and paper), active participation in discussions and practical skills. No prerequisites are necessary for exam registration.

Grading procedure

The grade of the module will be the grade of the exam.

Basis for

Research in this field
Laboratory Principles of Scanning Electron Microscopy
Modules referring to Elective Courses II - Physics

Code 8833273699

ECTS credits 2

Attendance time 1

Language of instruction English

Duration 1 Semester

Cycle each Summer Semester

Coordinator Prof. Dr. K.-E. Gottschalk, Faculty of Natural Science

Instructor(s) Prof. Dr. Ute Kaiser, Faculty of Natural Sciences

Allocation of study programmes Advanced Materials M.Sc., elective module, 2nd Semester

Recommended prerequisites None

Learning objectives Students who have successfully completed this module are able to
• prepare SEM sample
• perform bright-field and dark-field images and diffraction patterns in order to understand the defects in the specimen
• determine the spherical aberration coefficient

Syllabus In this module, the following topics will be covered:
• Modes of SEM operation: imaging, diffraction and spectroscopy
• SEM sample preparation
• Hands-on experience in imaging, diffraction and spectroscopy

Literature Will be announced in the lab course.

Teaching and learning methods Lab Course (equals 2 hours per week)

Workload 30 hours lab course (attendance time)
30 hours self-study and exam preparation
Total: 60 hours

<table>
<thead>
<tr>
<th>Assessment</th>
<th>The award of the credit points for this module is based on regular attendance and a written exam. No prerequisites are necessary for exam registration.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading procedure</td>
<td>The grade of the module will be the grade of the exam.</td>
</tr>
<tr>
<td>Basis for</td>
<td>Research in the field of Electron Microscopy</td>
</tr>
<tr>
<td>Code</td>
<td>8822873443</td>
</tr>
<tr>
<td>--------------------</td>
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<td>ECTS credits</td>
<td>2</td>
</tr>
<tr>
<td>Attendance time</td>
<td>1</td>
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<tr>
<td>Language of instruction</td>
<td>English</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Dean of Physics Studies</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Ute Kaiser</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>Master Advanced Materials, compulsory elective module, 3\textsuperscript{rd} Semester</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>-</td>
</tr>
</tbody>
</table>
| Learning objectives | Students who have successfully completed the lab course are able to  
\begin{itemize}  
\item prepare a cross-sectional TEM sample  
\item perform bright-field and dark-field images and diffraction patterns in order to understand the defects in the specimen  
\item determine the spherical aberration coefficient  
\item determine the chemical content by EDX analysis  
\end{itemize} |
| Syllabus           | In this module, the following topics will be covered:  
\begin{itemize}  
\item Modes of TEM operation: imaging, diffraction and spectroscopy  
\item TEM sample preparation  
\item Hands-on experience in imaging, diffraction and spectroscopy  
\item Determination of the spherical aberration coefficient of the objective lens in an uncorrected TEM, comparison to the aberration-corrected objective lens.  
\end{itemize} |
<p>| Literature         | -          |</p>
<table>
<thead>
<tr>
<th><strong>Teaching and learning methods</strong></th>
<th>1 week TEM Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workload</strong></td>
<td>Total: 60 hours</td>
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<tr>
<td><strong>Assessment</strong></td>
<td>The grade of the module will be the grade of the written exam. No prerequisites are necessary for exam registration.</td>
</tr>
<tr>
<td><strong>Grading procedure</strong></td>
<td>The grade of the module will be the grade of the exam.</td>
</tr>
<tr>
<td><strong>Basis for</strong></td>
<td>Research in the field of Materials Science and Imaging</td>
</tr>
</tbody>
</table>
Principles of Transmission Electron Microscopy und Seminar
Modules referring to Elective Courses II - Physics

Code 8822874121

ECTS credits 4

Attendance time 1

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Dean of Physics Studies

Instructor(s) Prof. Ute Kaiser

Allocation of study programmes Master Advanced Materials, compulsory elective module, 3rd Semester

Recommended prerequisites -

Learning objectives Students who have successfully completed the lecture and seminar

• are able to describe the function of basic components of a transmission electron microscope,
• are able to understand basic TEM modes: imaging, diffraction and spectroscopy.

Syllabus In this module, the following topics will be covered:

• Components of the TEM including the aberration corrector
• Physical phenomena of electron-matter interaction

### Teaching and learning methods

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>2 hours per week</td>
</tr>
<tr>
<td>Exercise</td>
<td>1 h per week</td>
</tr>
</tbody>
</table>

### Workload

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture (attendance time)</td>
<td>30 hours</td>
</tr>
<tr>
<td>Seminar (attendance time)</td>
<td>15 hours</td>
</tr>
<tr>
<td>Self-study and exam preparation</td>
<td>75 hours</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>120 hours</strong></td>
</tr>
</tbody>
</table>

### Assessment

The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.

### Grading procedure

The grade of the module will be the grade of the exam.

### Basis for

Research in field of TEM
Smart Materials
Modules referring to Elective Courses II - Physics

Code 8812874199

ECTS credits 3

Attendance time 2

Language of instruction English

Duration 1 Semester

Cycle each Semester

Coordinator Dean of Physics Studies

Instructor(s) Dr. Masoud Amirkhani.

Allocation of study programmes Physics M.Sc., elective module, 1st or 2nd Semester

Recommended prerequisites A basic knowledge about polymers will be sufficient

Learning objectives Responsive soft matter shows significant property changes in response to electrical stimulation, PH and other external stimuli, which can be used as actuator, sensor and energy harvester. These types of materials possess very promising potential to be used for minimally invasive medicine, space and automobile application.

Additionally, soft lithography has been proposed as a cheap and easy method to replace expensive conventional lithography. In this lecture, we will discuss cutting-edge research and technology related to artificial muscles and soft lithography. Furthermore, you will learn the effect of external stimuli on the nanometer and sub-nanometer thick polymeric layer.

Syllabus
• Responsive polymers
• Temperature- and PH-responsive polymers
• Electroactive polymers
• Sensing and actuating
• Soft robotic
• Medical application
• Space application
• Soft nanolithography
• Phase separation of block copolymers
• External stimuli
• Nanometer and sub-nanometer polymers on surface
Literature

- Electroactive Polymers for Robotic Applications Artificial Muscles and Sensors, Kwang J. Kim and Satoshi Tadokoro
- Biomedical Applications of Electroactive Polymer Actuators, Federico Carpi, Elisabeth Smela
- Electroactive Polymer Gel Robots Modelling and Control of Artificial Muscles, Mihoko Otake

Teaching and learning methods

Lecture 2 h/week

Workload

30 h Lecture (Attendance)
60 h Self study and exam preparation
Total: 90 h

Assessment

The grade of the module will be the grade of the oral exam. Prerequisite for exam registration is passing the pre-course. The specific form and extent of the exam as well as the exact type of the obligatory pre-course will be determined and announced by the lecturer at the beginning of the semester.

Grading procedure

The grade of the module will be the grade of the exam.

Basis for

Research project in Biophysics and experimental Physics.
Structure Physics
Modules referring to Elective Courses II - Physics

Code 8812872502

ECTS credits 6

Attendance time 6

Language of instruction English

Duration 1 Semester

Cycle each Summer Semester

Coordinator Dean of Physics Studies

Instructor(s) Prof. Dr. Ute Kaiser, Prof. Dr. Harald Rose

Allocation of study programmes Physics M.Sc., elective module, 1st or 2nd semester
Wirtschaftsphysik M.Sc., elective module, 1st – 3rd semester

Recommended prerequisites Undergraduate physics and mathematics, some experience in programming would be helpful

Learning objectives The objectives of this course are to teach fundamental principles and introduce the state-of-the-art instrumentation for probing atomic (and electronic) structures with electrons (X-rays, neutrons), along with the skill to transfer the theory taught during the course to practical computer code or talk. Each student will have to solve a dedicated problem related to one of the topics addressed during the lectures. These problems will be addressed in a student talk, along with a detailed explanation of the background of the implemented theory or a numerical solution. The student will also perform two experiments on our Cs-corrected TITAN80-300 on high-resolution TEM.

Syllabus 1) Introduction into structure physics (Bragg and Laue, history, instrumentation)
2) The symmetry of crystals – space groups
3) Basics of geometrical optics – paraxial approximation, Scherzer theorem, aberrations, correction of aberrations
4) Basics of Fourier optics – Sommerfeld diffraction, basics for Abbe imaging theory
5) Basics of contrast in TEM – scattering amplitude, scattering cross section, electron optical refraction index, Born approximation, high energy
approximation, multislice algorithm, propagation and image formation, image intensity
6) Basics of HRTEM imaging – experiment and calculation

Student's project: Evaluate one of the problems below, then document the problem and the approach used to solve it. Present and discuss the project during the exercises.

- Generate atom positions within the unit cell from symmetry operators and replicate this unit cell a given amount of times, building a crystal – build in pre-defined space group numbers
- Calculation of the electron paths in a magnetic field
- Chromatic and spherical aberrations- calculation of the influence and different accelerating voltages
- How a hexapole corrector works? Calculation of ray paths.
- Fresnel and Fraunhofer diffraction in TEM
- Calculation of the scattering amplitude and the scattering cross-section in firth Born approximation and high-energy approximation
- Compute an electron diffraction pattern, the projected potential and the image contrast using the multislice algorithm for a defined structure
- Calculation of the amplitude and phase contrast transfer function of different objects and imaging conditions.

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Links to relevant literature and programming guides will be provided on the course website <a href="http://www.uni-ulm.de/einrichtungen/hrem/lehreteaching.html">http://www.uni-ulm.de/einrichtungen/hrem/lehreteaching.html</a></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
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</thead>
<tbody>
<tr>
<td>Two block for 1 week each (corresponding to 3 hours per week)</td>
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<tr>
<td>Seminars/Exercises/Experiment (2 hours per week)</td>
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<table>
<thead>
<tr>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 hours lecture (attendance time)</td>
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<tr>
<td>30 hours exercise (attendance time)</td>
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<tr>
<td>105 hours self-study and exam preparation</td>
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<tr>
<td>Total: 180 hours</td>
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<table>
<thead>
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<tbody>
<tr>
<td>The grade of the module will be the grade of the oral exam. Prerequisite for exam registration is passing the pre-course (to be defined by the examiner).</td>
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</table>

<table>
<thead>
<tr>
<th>Grading procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>The grade of the module will be the grade of the exam.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Basis for</th>
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</thead>
<tbody>
<tr>
<td>Research in the fields of condensed matter physics.</td>
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</table>
Biology
Modules referring to Compulsory Modules

Code 8822874098

ECTS credits 4

Attendance time keine Angaben

Language of instruction English

Duration 1 Semester

Cycle each Semester

Coordinator Prof. Dr. K.-E. Gottschalk

Instructor(s) Prof. Dr. Paul Walther, PD Dr. Andres Ziegler; Dr. Tamas Röszer

Allocation of study programmes MSc Advanced Materials, semester 1

Recommended prerequisites Fundamentals of Biology

Learning objectives Students should be able to
- understand central problems of biology and cell biology.
- understand links between different fields of biosciences.
- follow the Biomaterials lectures in 2nd and 3rd semester.

Syllabus Biomolecules
- Water and the fitness of the environment
- Carbon and the molecular diversity of life
- Major classes of biomolecules
- Structure and function of macromolecules
- Introduction to metabolism, enzymes
Cell morphology and gene expression
- A tour of the cell
- Membrane structure and function
- The cell cycle
- The molecular basis of inheritance
- From gene to protein
- Regulation of gene expression
Intracellular compartments and protein sorting
- Vesicular transport
- Cytoskeleton and mitosis
Cellular respiration
- Harvesting chemical energy
  Structure and function of cellular membranes
    - Cell-cell contacts and cell adhesion
    - Cell-environment interactions
    - Sensing
    - Structure and function of the extracellular matrix
  Cellular model systems
    - Development
    - Animal development
    - Development genes and their detection
  Functional anatomy
    - Muscle function
    - Nervous system
    - Tissues
  Endocrinology
    - Chemical signals in animals
    - Blood glucose and adrenal gland hormones in non-vertebrates
  Circulation and gas exchange
    - Circulation and gas exchange
    - Gas exchange in animals

**Literature**
- Handouts

**Teaching and learning methods**
Lecture, 4 h/week

**Workload**
Total 150 h
64 h presence
70 h preparation and post-processing
16 h exam preparation

**Assessment**
The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.

**Grading procedure**
The grade of the module will be the grade of the exam.

**Basis for**
MSc Advanced Materials
### Chemistry
**Modules referring to Compulsory Modules**

<table>
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<td>Language of instruction</td>
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<tr>
<td>Duration</td>
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</tr>
<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. Thorsten M. Bernhardt, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. Thorsten M. Bernhardt, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>MSc Advanced Materials, semester 1</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>Fundamentals in Chemistry</td>
</tr>
<tr>
<td><strong>Learning objectives</strong></td>
<td>Physical Chemistry</td>
</tr>
</tbody>
</table>
| Students should be able | - to apply the laws and principles of thermodynamics and of reaction kinetics when analyzing chemical reactions with respect to energy conversion, equilibrium and reaction rate.  
   - to describe the influence of external parameters on chemical reactions.  
   - to describe atomic structures and the formation of bonds between atoms in terms of quantum mechanics.  
   - to understand and describe the principles of selected spectroscopy techniques in chemistry.  
   - to interpret simple spectra. |
| **Syllabus**          | Physical Chemistry |
|                       | - Thermodynamics: The laws of thermodynamics, enthalpy, entropy, free-energy, absolute zero of temperature, applications to chemical reactions, chemical equilibrium.  
   - Reaction kinetics: Reaction rate / rate equation, reaction order, dependence of reaction rate on temperature, activation energy, catalysis.  
   - Quantum chemistry: Properties of waves and the wave-nature of matter, atomic structure and orbital theory, atomic orbitals (hydrogen atom) and molecular orbitals, principles of chemical bond formation. |
- Spectroscopy: Basic spectroscopy techniques in chemistry.

**Literature**

**Teaching and learning methods**
- Lecture 4 h/week
- Problem solving 1 h/week

**Workload**
- Total: 120 h
- Lecture: 64 h presence
- Problem solving: 16 h presence
- 24 h preparation and post processing
- Exam: 16 h preparation

**Assessment**
- The grade of the module will be the grade of the written exam. Prerequisite for exam registration is passing the pre-course (to be defined by the examiner).

**Grading procedure**
- The grade of the module will be the grade of the exam.

**Basis for**
- MSc Advanced Materials
## Materials and Engineering Science

Modules referring to Compulsory Modules

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<td>Duration</td>
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<td>Cycle</td>
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</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. U. Herr, Faculty of Engineering, Computer Science and Psychology</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. U. Herr, Faculty of Engineering, Computer Science and Psychology Prof. Dr. F. Scholz, Faculty of Engineering, Computer Science and Psychology</td>
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<tr>
<td>Allocation of study programmes</td>
<td>MSc Advanced Materials, semester 1</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>Fundamentals of mathematics, physics and chemistry</td>
</tr>
<tr>
<td>Learning objectives</td>
<td>Materials Science I</td>
</tr>
<tr>
<td></td>
<td>Students should be able to</td>
</tr>
<tr>
<td></td>
<td>- classify metallic, ceramic and polymeric materials based on their structure on the atomic scale, microstructure and macroscopic properties.</td>
</tr>
<tr>
<td></td>
<td>- analyze different materials with respect to mechanical strength.</td>
</tr>
<tr>
<td></td>
<td>- understand the physical basis for thermal, electrical and magnetic properties of solid materials.</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>Students should be able to</td>
</tr>
<tr>
<td></td>
<td>- perform circuit analysis of linear DC and AC (RLC) circuits.</td>
</tr>
<tr>
<td></td>
<td>- explain the basics of semiconductor physics.</td>
</tr>
<tr>
<td></td>
<td>- explain how basic semiconductor devices work.</td>
</tr>
<tr>
<td></td>
<td>- handle and evaluate measured data on a basic level.</td>
</tr>
<tr>
<td></td>
<td>- convert analogue data into digital data.</td>
</tr>
<tr>
<td></td>
<td>- handle digital data.</td>
</tr>
<tr>
<td></td>
<td>- specify advantages and problems of digital data processing.</td>
</tr>
</tbody>
</table>

### Syllabus

| Materials Science I |  |
- Classification of materials with respect to chemical bond and structure.
- Crystal structure: Symmetry classes, lattices, reciprocal lattice, diffraction.
- Defects in solids: Point defects, dislocations, grain and phase boundaries.
- Characterization of the microstructure: Microscopic methods (optical, SEM),
  diffraction techniques (XRD, TEM), scanning probe techniques (introduction).
- Phase diagrams: Thermodynamics of solutions, chemical potential, phase
  equilibrium, basic types of phase diagrams, important examples.
- Transport: Diffusion (macroscopic and microscopic description), diffusion at
  surfaces and interfaces, electromigration, thermotransport.
- Phase transformations: Thermodynamics and kinetics, diffusive
  transformations, non-diffusive transformations.
- Mechanical properties: Elasticity, plastic deformation, viscous flow and creep,
  fracture.

Electrical Engineering

- Circuit analysis: Network analysis, Thevenin and Norton equivalent circuits,
  superposition principle, linearity, capacitors & inductors, transformers
- Analysis of transients: Frequency analysis, filters etc.: Frequency response,
  logarithmic scale, Bode diagram, low pass, high pass, 2nd order low pass etc.
- Fourier and Laplace transformation: Transfer function, step, pulse response,
  convolution
- Semiconductors: Band structure, density of states, Fermi statistics, impurity
  conduction, mobility, diffusion. Hall effect
- Diodes: p-n-junction, load line analysis, pn as capacitance, Schottky diode
- Transistors: Bipolar transistor (band structure, common base, common emitter,
  amplification), Field Effect Transistor (Structure, operation, enhancement and
  depletion); load line analysis
- Devices for measurement: Operational amplifier, basics, adder, subtractor,
  integrator, differentiator, logarithmiser
- Probability distribution functions: Binomial, Poisson, Gauss
- Signal filtering, noise : Thermal, shot, 1/f, distribution, generation-
  recombination
- Digital Signal Processing: basic logic operations, adders, flip-flop,
- Digitization: Basics, sampling theorem, DA and AD converters, Digital filters, z-
  transformation

Literature

Materials Science I


Electrical Engineering

- Hambley, Allan R.: Electrical Engineering. Prentice Hall, Upper Saddle River,
  2002.
  1995.
- Profos, P. and T. Pfeifer: Handbuch der industriellen Messtechnik. R.

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Materials Science I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lecture 3 h/week</td>
</tr>
<tr>
<td></td>
<td>Solving problems 1 h/week</td>
</tr>
<tr>
<td></td>
<td>Electrical Engineering</td>
</tr>
<tr>
<td></td>
<td>Lecture 3 h/week</td>
</tr>
<tr>
<td></td>
<td>Solving problems 1 h/week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Materials Science I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lecture:</td>
</tr>
<tr>
<td></td>
<td>48 h presence</td>
</tr>
<tr>
<td></td>
<td>38 h preparation and revision</td>
</tr>
<tr>
<td></td>
<td>Solving problems:</td>
</tr>
<tr>
<td></td>
<td>16 h presence</td>
</tr>
<tr>
<td></td>
<td>32 h revision</td>
</tr>
<tr>
<td></td>
<td>Exam:</td>
</tr>
<tr>
<td></td>
<td>16 h preparation</td>
</tr>
<tr>
<td></td>
<td>Electrical Engineering</td>
</tr>
<tr>
<td></td>
<td>Lecture:</td>
</tr>
<tr>
<td></td>
<td>48 h presence</td>
</tr>
<tr>
<td></td>
<td>38 h preparation and revision</td>
</tr>
<tr>
<td></td>
<td>Solving problems:</td>
</tr>
<tr>
<td></td>
<td>16 h presence</td>
</tr>
<tr>
<td></td>
<td>32 h revision</td>
</tr>
<tr>
<td></td>
<td>Exam:</td>
</tr>
<tr>
<td></td>
<td>16 h preparation</td>
</tr>
</tbody>
</table>

| Assessment | The grade of the module will be the grades of the written exams. No prerequisites are necessary for exam registration. |

| Grading procedure | The grade of the module will be the average of the individual exam grades weighted by the credit points of the individual exams. |

| Basis for | MSc Advanced Materials, Focus Nanomaterials, Materials Science Lab and Advanced Materials Science |
# Materials Chemistry

Modules referring to Compulsory Modules

<table>
<thead>
<tr>
<th>Code</th>
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</thead>
<tbody>
<tr>
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<td>Attendance time</td>
<td>2</td>
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<tr>
<td>Language of instruction</td>
<td>English</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Cycle</td>
<td>each Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. K.-E. Gottschalk, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. Max Fichtner, Dr. Elena Mena-Osteritz</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>MSc Advanced Materials, semester 2</td>
</tr>
<tr>
<td>Recommended prerequisites</td>
<td>-</td>
</tr>
<tr>
<td>Learning objectives</td>
<td>Students should be able to</td>
</tr>
<tr>
<td></td>
<td>a) <em>Chemistry of Inorganic Solids:</em></td>
</tr>
<tr>
<td></td>
<td>- describe the structure, bonding and the electronic structure of an inorganic solid</td>
</tr>
<tr>
<td></td>
<td>- decide which method of characterization can be applied for different inorganic solid materials</td>
</tr>
<tr>
<td></td>
<td>- describe basic synthetic methods for the fabrication of inorganic materials</td>
</tr>
<tr>
<td></td>
<td>- correlate the electrical, optical and magnetic properties of the material with its nanostructure, defect structure</td>
</tr>
<tr>
<td></td>
<td>b) <em>Organic Materials</em></td>
</tr>
<tr>
<td></td>
<td>- describe the fundamentals in organic materials formation</td>
</tr>
<tr>
<td></td>
<td>- represent and understand the different classes of organic materials</td>
</tr>
<tr>
<td></td>
<td>- describe the application’s spectrum in material chemistry</td>
</tr>
</tbody>
</table>

### Syllabus

**Materials Chemistry**

<table>
<thead>
<tr>
<th>a) <em>Solids State Chemistry:</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure of solids, basic crystallography, characterization of solids</td>
</tr>
</tbody>
</table>
Bonding in solids, Real structure of crystals, Solid state reaction, sol-gel method, hydrothermal synthesis, vapor phase transport, methods for crystal growth, structure-property relations

b) Organic Materials and Structure Formation

including Inorganic Chemistry: Atoms, Hydrogen, Halogens, Chalcogens

In terms of: Van der Waals, interaction forces, electrostatic interaction between systems

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Lecture 3 h/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>42 h lecture (presence)</td>
</tr>
<tr>
<td></td>
<td>62 h preparation and post processing</td>
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<tr>
<td></td>
<td>16 h exam preparation</td>
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<table>
<thead>
<tr>
<th>Assessment</th>
<th>The grade of the module will be the grade of the written exam. No prerequisites are necessary for exam registration.</th>
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<tbody>
<tr>
<td>Grading procedure</td>
<td>The grade of the module will be the grade of the exam.</td>
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<tr>
<td>Basis for</td>
<td>MSc Advanced Materials</td>
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Date printed: 18. Juli 2018
### Mathematics
Modules referring to Compulsory Modules

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</tr>
<tr>
<td><strong>Attendance time</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Language of instruction</strong></td>
<td>English</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>1 Semester</td>
</tr>
<tr>
<td><strong>Cycle</strong></td>
<td>each Semester</td>
</tr>
<tr>
<td><strong>Coordinator</strong></td>
<td>Prof. Dr. K.-E. Gottschalk, Faculty of Natural Sciences</td>
</tr>
<tr>
<td><strong>Instructor(s)</strong></td>
<td>Dr. Vincenzo Tamma, Faculty of Natural Sciences</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Allocation of study programmes</strong></th>
<th>MSc Advanced Materials, semester 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recommended prerequisites</strong></td>
<td>Fundamentals of mathematics</td>
</tr>
<tr>
<td><strong>Learning objectives</strong></td>
<td>This course gives an overview of essential mathematical methods for the solution of generic problems in Physics and related subjects. Specific examples of important physical applications will be given. The course aims to provide the student with the expected mathematical competency for further courses in different areas of Physics and related subjects.</td>
</tr>
</tbody>
</table>
| **Syllabus**                      | - Ordinary differential equations and systems of differential equations  
- Linear vector spaces, Vector and Matrix Analysis  
- Fourier Analysis  
- Functions of complex variable and integral calculus |
| **Literature**                    | Bibliographical references will be given to the students for each different topic addressed in the course. |
| **Teaching and learning methods** | Lecture 3h/week  
Problem solving 2h/week |
### Workload
- 48 h presence
- 16 h preparation and revision

Solving problems:
- 32 h presence
- 64 h preparation and revision

Exam:
- 16 h preparation

### Assessment
The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.

### Grading procedure
The grade of the module will be the grade of the exam.

### Basis for
MSc Advanced Materials
Physics I
Modules referring to Compulsory Modules

Code  8822872896

ECTS credits  10

Attendance time  6

Language of instruction  English

Duration  1 Semester

Cycle  each Semester

Coordinator  Prof. Dr. K.-E. Gottschalk, Faculty of Natural Sciences

Instructor(s)  Prof. Dr. U. Herr; Faculty of Engineering, Computer Science and Psychology

Dr. L. Rogers, Faculty of Natural Sciences

Allocation of study programmes  MSc Advanced Materials, semester 1 and 2

Recommended prerequisites  Fundamentals of physics (mechanics, electricity, optics, quantum mechanics) and Fundamentals of mathematics (differentiation, integration, complex calculus, ordinary and partial differential equations)

Learning objectives  Physics I
Students should be able to
- relate the atomic structure of materials to physical properties.
- classify materials according to atomic structure and involved chemical bonds.
- describe electrons in a solid state system: atom vs. solid.
- describe lattice vibrations and their influence on material properties: classical vs. quantum mechanical description, statistics of bosons.
- explain optical properties of dielectrics and metals by microscopic models.
- understand that classical physics often fails to predict material properties and quantum effects have to be taken into account.

Physics Lab
Students be able to
- determine basic properties of a solid experimentally by
  - structure analysis by X-ray diffraction
  - electronic core level analysis by X-ray photoelectron spectroscopy
  - electric conductivity measurement.
- use cryostats to perform experiments at low temperature.
- design and carry out advanced experiments in solid state physics.
- write scientific lab reports.
**Syllabus**

Physics I

- Basic classification of solids by means of structure, bonds and properties.
- Experimental determination of structure.
- Lattice vibrations and phonons: specific heat.
- Properties of the electron shell in solids, free electrons.
- Optical properties of solids.

Physics Lab

- Specific heat of simple metals between 2 K and 20 K
- Advanced measurement techniques: Application of a Lock-in amplifier
- Determination of electrical conductivity of metals and semiconductors between 2 K and 70 K
- X-ray photoelectron spectroscopy (XPS) on Au and Au2O3
- Optical properties of Au films and Au nanoparticles.

**Literature**

Physics I


Physics Lab

Handouts

**Teaching and learning methods**

Physics I

- Lecture 3 h/week
- Tutorial/Problem solving 4 x 2h

Physics Lab

- 4 h/week

**Workload**

Physics I Total 150 h

Lecture: 48 h lecture

68 h preparation and post-processing

Seminar: 8 h presence

8 h solving problems, revision

Exam: 2 h exam + 16 h preparation

Physics Lab Total 120 h

20 h laboratory (presence)

20 h preparation

80 h revision, writing reports

**Assessment**

The module will be passed once the written or oral (depending on the number of participants) exam and practical work have been passed.
Grading procedure  The grade of the module will be the average of the individual exam grades weighted by the credit points of the individual exams.

Basis for  MSc Advanced Materials
Physics II
Modules referring to Compulsory Modules

**Code** 8822874160

**ECTS credits** 5

**Attendance time** 3

**Language of instruction** English

**Duration** 1 Semester

**Cycle** each Summer Semester

**Coordinator** Prof. Dr. B. Koslowski, Faculty of Natural Sciences

**Instructor(s)** Prof. Dr. B. Koslowski, Faculty of Natural Sciences

**Allocation of study programmes** MSc Advanced Materials, semester 2, Nanomaterials

**Recommended prerequisites** Fundamentals of mathematics and physics

**Learning objectives** Students should be able to
- relate macroscopic properties of materials (electronic, optical, magnetic) to microscopic properties (e.g., structural symmetry).
- relate macroscopic optical materials properties to microscopic models.
- describe the most important phenomena (e.g., dia-, para-, ferro-, antiferro-, ferrimagnetism) and the basic ideas to explain them microscopically.

**Syllabus**
- From free electrons to nearly free electrons: band structure & band gaps, Fermi surfaces, semiconductors, insulators
- Quasi-classical description of electron dynamics: effective mass, electrons & holes
- Semiconductors: Effects of doping
- Optics of metals: plasmons
- Magnetism: Curie law, Hund’s rule, Pauli susceptibility, ferromagnetic phenomena & descriptions

**Literature** For general literature on solid state physics see module *Physics I*
Additionally:

- Handouts

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Lecture 2 h/week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem solving 1h/week</td>
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</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Total: 120 h</th>
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<tbody>
<tr>
<td>Lecture: 28 h presence</td>
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<tr>
<td>32 h preparation and post processing</td>
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<tr>
<td>Problem solving: 14 h presence</td>
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<tr>
<td>30 h preparation and post processing</td>
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<tr>
<td>Exam: 16 h preparation</td>
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<table>
<thead>
<tr>
<th>Assessment</th>
<th>The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.</th>
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<table>
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<th>The grade of the module will be the grade of the exam.</th>
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<table>
<thead>
<tr>
<th>Basis for</th>
<th>MSc Advanced Materials, Nanomaterials</th>
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## Materials Science Laboratory

**Modules referring to Compulsory Modules**

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<td><strong>Language of instruction</strong></td>
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</tr>
<tr>
<td><strong>Duration</strong></td>
<td>1 Semester</td>
</tr>
<tr>
<td><strong>Cycle</strong></td>
<td>each Summer Semester</td>
</tr>
<tr>
<td><strong>Coordinator</strong></td>
<td>Prof. Dr. U. Herr, Faculty of Engineering, Computer Science and Psychology</td>
</tr>
<tr>
<td><strong>Instructor(s)</strong></td>
<td>Prof. Dr. U. Herr, Faculty of Engineering, Computer Science and Psychology</td>
</tr>
<tr>
<td><strong>Lecturers of the Faculty of Engineering, Computer Science and Psychology</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Allocation of study programmes
- MSc Advanced Materials, semester 2, Nanomaterials

### Recommended prerequisites
- Module Materials and Engineering Science

### Learning objectives
- Students should be able to
  - operate modern instruments
  - apply their fundamental knowledge of Materials Science
  - be able to present and report own experimental work/results

### Syllabus
- Lambda probe
- Optical properties of ceramics
- Kerr magnetometry and microscopy
- Impedance spectroscopy
- Elastic properties
- Hydrogen storage

### Literature

<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
<th>Laboratory: 3 h/week</th>
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<tbody>
<tr>
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<td>Seminar: 1 h/week</td>
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<table>
<thead>
<tr>
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<th>Total 150 h</th>
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<tbody>
<tr>
<td>36 h presence</td>
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<tr>
<td>71 h preparation, revision, writing</td>
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<tr>
<td>43 h preparation of presentation,</td>
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<tr>
<td>presentation, paper writing</td>
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| Assessment                         | The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration. |

| Grading procedure                  | The grade of the module will be the grade of the exam. |

| Basis for                          | MSc Advanced Materials, Nanomaterials |
Scientific Method Training
Modules referring to Compulsory Modules

Code 8822874099

ECTS credits 3

Attendance time 2

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Prof. Dr. K.-E. Gottschalk, Faculty of Natural Sciences

Instructor(s) Dr. C. Röcker, Faculty of Natural Sciences

Allocation of study programmes MSc Advanced Materials, semester 1

Recommended prerequisites Fundamental knowledge of lab work

Learning objectives Practical experience in basic physical experimental techniques relevant for Biophysics and analysis of experimental data with critical discussion.

Syllabus
- Mechanical oscillations
- Thermic radiation
- Optical interference and spectrometry
- Oscillating electric circuits

Literature Lab Manual

Teaching and learning methods Lab work with full-day experiments including introductory and final discussions.

Workload
- 45 hours laboratory course (attendance time)
- 75 hours self-study, data analysis, report writing
- Total: 120 hours

Master of Science Advanced Materials Date printed: 18. Juli 2018
<table>
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<th>The grade of the module will be the grade of the oral or written (depending on the number of participants) exam. No prerequisites are necessary for exam registration.</th>
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<td><strong>Basis for</strong></td>
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**Additive Key Qualifications**
Modules referring to Additive Key Qualifications

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<td>Attendance time</td>
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<td>Duration</td>
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<td>Cycle</td>
<td>each Semester</td>
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<td>Coordinator</td>
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<td>Teaching and learning methods</td>
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**Grading procedure**
The grade of the module will be the average of the individual exam grades weighted by the credit points of the individual exams.

Master of Science Advanced Materials
Date printed: 18. Juli 2018

page 93 of 101
Basis for

No english version available yet.
### Additive Key Qualifications

#### Modules referring to Additive Key Qualifications

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<td>1 Semester</td>
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<tr>
<td>Cycle</td>
<td>each Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Leader of the language center of the University of Ulm Instructor(s)</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Leader of the language center of the University of Ulm Instructor(s)</td>
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<td>Allocation of study programmes</td>
<td>Master Advanced Materials, compulsory module, 1.-3. Semester</td>
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<td>Recommended prerequisites</td>
<td>Formal prerequisites (according to Study order and examination regulations): none</td>
</tr>
<tr>
<td>Learning objectives</td>
<td>Intercultural competence and foreign linguistic knowledge; knowledge and abilities in the areas of Works in the team, communication and presentation learns; reflecting competence, communication competence and argumentation competence.</td>
</tr>
<tr>
<td>Syllabus</td>
<td>Depends on the chosen course</td>
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<tr>
<td>Literature</td>
<td>is made available in the chosen course</td>
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<tr>
<td>Teaching and learning methods</td>
<td>in general: seminar (2 hours per week)</td>
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<td>Workload</td>
<td>Presence study: 30 H</td>
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<tr>
<td></td>
<td>Self study: 60 H</td>
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<td>Total: 90 H</td>
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<tr>
<td><strong>Basis for</strong></td>
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German Language
Modules referring to Additive Key Qualifications

Code 8822870974
ECTS credits 8
Attendance time 10
Language of instruction German
Duration 3 Semester
Cycle each Semester
Coordinator Dr. Timm, Centre for Languages and Philology
Instructor(s) Lecturers from Centre for Languages and Philology

Allocation of study programmes MSc Advanced Materials, semester 1,2,3
Recommended prerequisites None

Learning objectives Development of language skills: Listening, speaking, reading, writing.
Depending on the students language level a specific course is chosen, the courses may cover approx. 1 level of the CEFR
German for Advanced Material, Energy Science and Technology and Finance 1 to 3
Level A1, CEFR (Common European Framework of Reference for Languages)
Students should be able to
- understand and use familiar, everyday expressions and very simple sentences, which relate to the satisfying of concrete needs.
- introduce him/herself and others as well as ask others about themselves – e.g. where they live, who they know and what they own – and can respond to questions of this nature.
- communicate in a simple manner if the person they are speaking to speaks slowly and clearly and is willing to help.
Level A2, CEFR
Students should be able to
- understand sentences and commonly used expressions associated with topics directly related to his/her direct circumstances (e.g. personal information or information about his/her family, shopping, work, immediate surroundings).
- make him/herself understood in simple, routine situations dealing with a simple and direct exchange of information on familiar and common topics.
- describe his/her background and education, immediate surroundings and other things associated with immediate needs in a simple way.

Level B1 and above, CEFR

Students should be able to
- understand the main points when clear, standard language is used and the focus is on familiar topics associated with work, school, leisure time, etc.
- deal with most situations typically encountered when travelling in the language region.
- express him/herself simply and coherently regarding familiar topics and areas of personal interest.
- report on experiences and events, describe dreams, hopes and goals as well as make short statements to justify or explain his/her own views and plans.

Syllabus
For the three courses alike:
- vocabulary training
- grammar training
- development of communication skills

Literature
Menschen – Deutsch als Fremdsprache, Max Hueber Verlag, 2013.
Kursbuch A1, A2 and B1

Teaching and learning methods
lecture/excercise 4 h/week (semester 1 and 2) and 2h/week (semester 3)

Workload
Semester 1 and 2
Lecture 60 h
Preparation 30 h
Semester 3
Lecture 30 h
Preparation 30 h

Assessment
The module will be passed once all three exams have been passed.

Grading procedure
The grade of the module will be the average of the individual exam grades weighted by the credit points of the individual exams.
Basis for MSc Advanced Materials
# Master's Thesis

**Modules referring to Master Thesis**

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<tr>
<td>Duration</td>
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<tr>
<td>Cycle</td>
<td>each Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. K.-E. Gottschalk, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Examiners of Faculty of Natural Sciences or Computer Science, Engineering and Psychology or Medicine.</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>MSc Advanced Materials, semester 4</td>
</tr>
</tbody>
</table>

## Recommended prerequisites

**Formal prerequisites (according to Study order and examination regulations)**

**Prerequisites regarding to the contents:** Thematically relevant modules and lectures of the master course of studies

Research project to be carried out at an institute or institution of Ulm University. On request, it may be performed at a research institution not belonging to Ulm University or with a company engaged in research, development or production of modern functional materials.

The registration of the module must be carried out with board of examiners with the form intended for it!

## Learning objectives

Students who successfully passed this module

- have learned to integrate in a research team
- are able to investigate a topic in the current research in nanomaterials or biomaterials independently and according to the rules of good scientific practice, and to develop their own approach
- can prove and document their findings on scientific principles
- are able to motivate their solutions and defend their thesis in a scientific discussion

## Syllabus

- Execution of a theoretical or experimental research project
• Evaluation of the obtained results
• Discussion of the results in the context of the relative literature
• Documentation of the research project

<table>
<thead>
<tr>
<th>Literature</th>
<th>literature search is part of the assignment</th>
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<tbody>
<tr>
<td>Teaching and learning methods</td>
<td>Independent scientific work, professional discussions, working group seminars or seminars in the enterprise (28 CP) Presentation of the results of the work (2 CP); the presentation is public (working group, institute, faculty)</td>
</tr>
<tr>
<td>Workload</td>
<td>for literature work, experimental works and documentation: 900 h</td>
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<tr>
<td>Assessment</td>
<td>Written master's thesis and oral presentation of the results of the master's thesis.</td>
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<tr>
<td>Grading procedure</td>
<td>The grade of the module will be the grade of the exam. The module grade is based on the grades of the written master's thesis (28 credit points) and the presentation (2 credit points). The Transcript of Records only shows the calculated overall grade as an exam achievement.</td>
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<td>Basis for</td>
<td>PhD</td>
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