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# Module Catalogue

## Master Program Materials Science

### Faculty of Mathematics, Natural Sciences, and Materials Engineering

Examination regulations as of 20.11.2013

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You can see the other use cases of the modules in Digicampus.

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\* = At least one course for this module is offered in the current semester

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\* = At least one course for this module is offered in the current semester

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\* = At least one course for this module is offered in the current semester

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\* = At least one course for this module is offered in the current semester

<b>Module PHM-0144: Materials Physics</b> <i>Materials Physics</i>		6 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Electrons in solids</li> <li>• Phonons</li> <li>• Properties of metals, semiconductors and insulators</li> <li>• Application in optical, electronic, and optoelectronic devices</li> <li>• Dielectric solids, optical properties</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic terms and concepts of solid state physics like the free electron gas, electronic band structure, charge carrier statistics, phonons, doping and optical properties,</li> <li>• are capable to apply derived approximations as the effective mass or the electron-hole concept to describe basic characteristics of semiconductor materials,</li> <li>• have the competence to apply these concepts for the description of electric, electro-optic and thermal properties of solids and to describe their functionalities,</li> <li>• understand size effects on material physical properties.</li> <li>• Integrated acquirement of soft skills: Working with specialist literature, literature search and interdisciplinary thinking.</li> </ul>		
<b>Remarks:</b> compulsory module		
<b>Workload:</b> Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> basic knowledge of solid state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Materials Physics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		

**Contents:**

- Electrons in solids: Free electron gas, band structure, effective mass
- Lattice dynamics: Phonons, phonon dispersion, acoustic and optical phonons
- Properties of metals: Electrical conductivity, Fermi surfaces, thermal properties
- Properties of semiconductors: Pure, intrinsic semiconductors, equilibrium conditions, doping
- Properties of dielectric materials: Propagation of electromagnetic waves, frequency dependent optical properties, polarization effects.
- Application in devices: Heterostructures, Schottky contact, pn-junction, solar cell, light emission and technological aspects

**Literature:**

- Hummel R. E. : Electronic Properties of Materials Springer 2001 (UP1000 H925)
- Burns G.: Solid State Physics Academic Press 1990 (UP1000 B967)
- Ashcroft N. W. , Mermin N.D. : Solid State Physics (UP1000 A 824)
- Kittel C. : Introduction to Solid State Physics (UP1000 K 62)

**Assigned Courses:**

**Materials Physics** (lecture)

**Part of the Module: Materials Physics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Learning Outcome:**

see module description

**Assigned Courses:**

**Materials Physics (Tutorial)** (exercise course)

**Examination**

**Materials Physics**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Materials Physics



<b>Module PHM-0110: Materials Chemistry</b> <i>Materials Chemistry</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Revision of basic chemical concepts</li> <li>• Solid state chemical aspects of selected materials, such as <ul style="list-style-type: none"> <li>◦ Thermoelectrics</li> <li>◦ Battery electrode materials, ionic conductors</li> <li>◦ Hydrogen storage materials</li> <li>◦ Data storage materials</li> <li>◦ Phosphors and pigments</li> <li>◦ Heterogeneous catalysis</li> <li>◦ nanoscale materials</li> </ul> </li> </ul>		
<b>Learning Outcomes / Competences:</b> The students will <ul style="list-style-type: none"> <li>• be able to apply basic chemical concepts on materials science problems,</li> <li>• broaden their ability to derive structure-property relations of materials combining their extended knowledge about symmetry-related properties, chemical bonding in solids and chemical properties of selected compound classes,</li> <li>• be able to assess synthetic approaches towards relevant materials,</li> <li>• acquire skills to perform literature research using online data bases.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> The lecture course is based on the Bachelor in Materials Science courses Chemie I and Chemie III (solid state chemistry).		
<b>Frequency:</b>	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Materials Chemistry</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see description of module		
<b>Contents:</b> see description of module		

**Literature:**

- A. R. West, Solid State Chemistry, John Wiley, Chichester.
- U. Müller, Inorganic Structural Chemistry, Wiley-VCH.
- R. Dronskowski, Computational Chemistry of Solid State Materials, Wiley VCH.
- Textbooks on Basics of Inorganic Chemistry such as J. E. Huheey, E. Keiter, R. Keiter, Anorganische Chemie, de Gruyter, or equivalents.
- Moreover, selected reviews and journal articles will be cited on the slides.

**Part of the Module: Materials Chemistry (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Learning Outcome:**

see description of module

**Contents:**

see description of module

**Literature:**

see associated lecture

**Examination**

**Materials Chemistry**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

only in the winter semester

**Examination Prerequisites:**

Materials Chemistry

**Description:**

ab dem WiSe 2023/4 wird nur noch die Modulprüfung angeboten, jedoch keine Vorlesung mehr  
from winter term 2023/4 on only the exam will be conducted, but no lecture anymore

<b>Module PHM-0117: Surfaces and Interfaces</b> <i>Surfaces and Interfaces</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Manfred Albrecht		
<p><b>Contents:</b></p> <p>Introduction</p> <ul style="list-style-type: none"> <li>The importance of surfaces and interfaces</li> </ul> <p>Some basic facts from solid state physics</p> <ul style="list-style-type: none"> <li>Crystal lattice and reciprocal lattice</li> <li>Electronic structure of solids</li> <li>Lattice dynamics</li> </ul> <p>Physics at surfaces and interfaces</p> <ul style="list-style-type: none"> <li>Structure of ideal and real surfaces</li> <li>Relaxation and reconstruction</li> <li>Transport (diffusion, electronic) on interfaces</li> <li>Thermodynamics of interfaces</li> <li>Electronic structure of surfaces</li> <li>Chemical reactions on solid state surfaces (catalysis)</li> <li>Interface dominated materials (nano scale materials)</li> </ul> <p>Methods to study chemical composition and electronic structure, application examples</p> <ul style="list-style-type: none"> <li>Scanning electron microscopy</li> <li>Scanning tunneling and scanning force microscopy</li> <li>Auger – electron – spectroscopy</li> <li>Photo electron spectroscopy</li> </ul>		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students:</p> <ul style="list-style-type: none"> <li>have knowledge of the structure, the electronical properties, the thermodynamics, and the chemical reactions on surfaces and interfaces,</li> <li>acquire the skill to solve problems of fundamental research and applied sciences in the field of surface and interface physics,</li> <li>have the competence to solve certain problems autonomously based on the thought physical basics.</li> <li>Integrated acquirement of soft skills.</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>20 h studying of course content using literature (self-study)</p> <p>20 h studying of course content using provided materials (self-study)</p> <p>80 h studying of course content through exercises / case studies (self-study)</p> <p>60 h lecture and exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <p>The module "Physics IV - Solid State Physics" of the Bachelor of Physics / Materials Science program should be completed first.</p>		
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<b>Parts of the Module</b>
<b>Part of the Module: Surfaces and Interfaces</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> annually <b>Contact Hours:</b> 3
<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Literature:</b> <ul style="list-style-type: none"><li>• Ertl, Küppers: Low Energy Electrons and Surface Chemistry (VCH)</li><li>• Lüth: Surfaces and Interfaces of Solids (Springer)</li><li>• Zangwill: Physics at Surfaces (Cambridge)</li><li>• Feldmann, Mayer: Fundamentals of Surface and thin Film Analysis (North Holland)</li><li>• Henzler, Göpel: Oberflächenphysik des Festkörpers (Teubner)</li><li>• Briggs, Seah: Practical Surface Analysis I und II (Wiley)</li></ul>
<b>Assigned Courses:</b> <b>Surfaces and Interfaces</b> (lecture)
<b>Part of the Module: Surfaces and Interfaces (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> annually <b>Contact Hours:</b> 1
<b>Assigned Courses:</b> <b>Surfaces and Interfaces (Tutorial)</b> (exercise course)
<b>Examination</b> <b>Surfaces and Interfaces</b> written exam / length of examination: 90 minutes, graded <b>Examination Prerequisites:</b> Surfaces and Interfaces

<b>Module PHM-0287: Method Course: Spectroscopy of Organic Semiconductors</b> <i>Method Course: Spectroscopy of Organic Semiconductors</i>		8 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Wolfgang Brütting Dr. Alexander Hofmann		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Growth and characterisation of thin films (vapor deposition, spin coating, surface profiling, atomic force microscopy)</li> <li>• Optical spectroscopy and photophysics (ellipsometry, transmission, steady-state and time-resolved photoluminescence, orientation anisotropy)</li> <li>• Charge transport (space-charge limited current, field-effect mobility, doping)</li> <li>• Light-emitting diodes (different emitter types, device efficiency measurement and simulation)</li> <li>• Solar cells (different device architectures, power and quantum efficiency measurements)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• get familiar with the preparation of organic semiconductors as thin films and in devices and learn basic spectroscopic techniques to characterise them,</li> <li>• acquire skills to analyse properties of the materials taking into account their specific features,</li> <li>• and have the competence to comprehend and attend to current problems in the field of organic electronics.</li> <li>• Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to critically interpret experimental results.</li> </ul>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Basic knowledge of atomic and solid state physics, as well as elementary concepts of quantum physics.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Spectroscopy of Organic Semiconductors</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		
<b>Lehr-/Lernmethoden:</b> The basics for each topic will be taught in class, e.g. using black board and beamer presentation.		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)</li> <li>• A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)</li> <li>• S.R. Forrest: Organic Electronics (Oxford Univ. Press)</li> </ul>		
<b>Assigned Courses:</b> <b>Method Course: Spectroscopy of Organic Semiconductors</b> (lecture)		

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**Part of the Module: Method Course: Spectroscopy of Organic Semiconductors (Practical Course)**

**Mode of Instruction:** internship

**Language:** English / German

**Contact Hours:** 4

**Lehr-/Lernmethoden:**

After teaching in class, the students will go to the lab to get practical experience with each topic.

**Examination**

**Method Course: Spectroscopy of Organic Semiconductors**

report, graded

<b>Module PHM-0297: Method Course: Methods in Bioanalytics</b> <i>Method Course: Methods in Bioanalytics</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Janina Bahnemann		
<b>Contents:</b> <ul style="list-style-type: none"> <li>- Basic concepts of instrumental analytics, sensor technology, validation, quality assurance</li> <li>- Biological basics for sensor design and sample components</li> <li>- Biological markers, biomaterials and targets: bioreceptors: antibodies, enzymes, aptamers, cells, nanoparticles</li> <li>- Sensor principles / transducers: optical, thermal, electrochemical, electromechanical, colorimetric</li> <li>- Sensor materials (e.g., silicon, gold, plastics, polymers)</li> <li>- Immobilization of bioreceptors on sensor materials</li> <li>- Lateral flow assays, Point-of-Care diagnostics</li> <li>- Carbohydrate and lipid analysis: Chromatographic methods (HPLC, GC, DC, MS)</li> <li>- Amino acid analytics: HPLC, fluorescence spectroscopy</li> <li>- Nucleic acid analytics: PCR method, sequencing, electrophoresis, microarrays</li> <li>- Protein analytics: Chromatography, electrophoresis, spectroscopy, Bradford assay</li> <li>- Cell analytics: Flow cytometry and microscopy</li> <li>- Concepts and materials for sensor development and optimization: e.g., Microfluidics, additive manufacturing, nanoporous materials, nanoparticles, amplifiers</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Students will be able to use acquired analytical expertise to adequately describe and correlate basic principles of bioanalysis and their applications.</li> <li>• Students will be able to transfer acquired knowledge from the lecture to practical applications in the experimental practical course.</li> <li>• Students will demonstrate self-competence of work organization as well as social competence by working in small groups.</li> <li>• Students will learn to identify proteins using various analytical methods, to set up biosensors for measuring glucose concentrations, and to scientifically evaluate, comprehensibly record in writing, and present the practical results.</li> </ul>		
<b>Remarks:</b> ELECTIVE COMPULSORY MODULE Number of students will be limited to 9.		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> keine / none		<b>Credit Requirements:</b> Practical work and written report
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> 1. - 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> none	

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Methods in Bioanalytics</b> <b>Language:</b> German / English <b>Contact Hours:</b> 2
<b>Literature:</b> <ul style="list-style-type: none"><li>• Lottspeich and Engels: "Bioanalytik", Spektrum Akademischer Verlag, ISBN: 3-8274-2942-0</li><li>• Lottspeich and Engels: "Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology"</li><li>• Ozkan et al.: "Biosensors: Fundamentals, Emerging Technologies, and Application", CRC Press</li><li>• Yoon: "Introduction to Biosensors: From Electric Circuits to Immunosensors", Springer Verlag, ISBN: 978-3319801360</li><li>• Thieman: "Introduction to Biotechnology", Pearson, ISBN: 978-1292261775</li></ul>
<b>Assigned Courses:</b> <b>Methods in Bioanalytics</b>
<b>Part of the Module: Method Course: Methods in Bioanalytics (Practical Course)</b> <b>Language:</b> German / English <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Methods in Bioanalytics</b>
<b>Examination</b> <b>Method Course: Methods in Bioanalytics</b> report, Practical work and written report on practical work, graded



<b>Module PHM-0298: Method course: From macroscopic to microscopic ferroic properties</b> <i>Method course: From macroscopic to microscopic ferroic properties</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. István Kézsmárki		
<p><b>Contents:</b></p> <p>Within this course, the students will learn the basic concepts of ferroic properties, e.g. ferroelectricity and ferromagnetism, which play a key role in materials science and engineering, at cryogenic temperatures. This method course will teach the students to understand and perform experiments on ferroic materials first, on a macroscopic scale and, after having a fundamental understanding, microscopic measurements. Therefore, the students will be taught in preparing single crystals, planning complex measurement procedures, and evaluating the measured data.</p> <p>Magnetic Properties will be investigated via:</p> <ul style="list-style-type: none"> <li>• Magnetization measurements</li> <li>• Susceptibility measurements</li> <li>• Magnetic force microscopy (MFM)</li> </ul> <p>Electric Properties will be investigated via:</p> <ul style="list-style-type: none"> <li>• Linear and non-linear dielectric spectroscopy</li> <li>• SEM / EDX</li> <li>• Polarization measurements</li> <li>• Conductive atomic force microscopy (cAFM) / piezo force microscopy (PFM)</li> </ul>		
<p><b>Learning Outcomes / Competences:</b></p> <ul style="list-style-type: none"> <li>• fundamental knowledge of properties in electric and magnetic materials</li> <li>• instruction in experimental methods for investigation of ferroic properties of condensed matter</li> <li>• perform experiments at cryogenic temperatures</li> <li>• trained in planning and performing complex experiments</li> <li>• learn to evaluate and analyze the collected data</li> <li>• combining knowledge of macroscopic measurements to understand microscopic data to fully understand electric and magnetic properties</li> </ul>		
<p><b>Remarks:</b> ELECTIVE COMPULSORY MODULES</p>		
<p><b>Workload:</b> Total: 240 h</p>		
<p><b>Conditions:</b> Recommended: basic knowledge in solid state physics and ferroic properties</p>		<p><b>Credit Requirements:</b> Participation in laboratory course and oral examination.</p>
<p><b>Frequency:</b> each semester</p>	<p><b>Recommended Semester:</b></p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Method course: From macroscopic to microscopic ferroic properties</b> <b>Language:</b> English <b>Contact Hours:</b> 2</p>		

**Literature:**

- N.W. Ashcroft, N.D. Mermin, Festkörperphysik (Oldenbourg)
- Ch. Kittel, Einführung in die Festkörperphysik (Oldenbourg)
- V. K. Wadhawan, Introduction to ferroic materials (CRC Press)
- S. Kalinin, A. Gruverman, Scanning Probe Microscopy - Electrical and electromechanical phenomena at the nanoscale (Springer)
- A. K. Tagantsev, Domains in Ferroic Crystals and Thin films (Springer)

**Part of the Module: Method course: From macroscopic to microscopic ferroic properties (Practical Course)**

**Language:** English

**Contact Hours:** 4

**Examination**

**Method course: From macroscopic to microscopic ferroic properties**

oral exam / length of examination: 45 minutes, graded

<b>Module PHM-0363: Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics</b> <i>Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics</i>	8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Christoph Alexander Weber	
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Phase separation kinetics of liquid mixtures</li> <li>• Dynamics of simple fluids</li> <li>• Kinetics of semi-dilute, elastic, and inelastic gases</li> <li>• Self-propelled, aligning gases</li> <li>• Motility-induced phase separation</li> <li>• Long-range polar order in two-dimensional active systems</li> <li>• Active Brownian motion</li> <li>• Mixtures of hot and cold particles</li> <li>• Stochastic chemical reaction kinetics at non-dilute conditions</li> </ul>	
<b>Learning Outcomes / Competences:</b> Students will learn the following hard skills: <ul style="list-style-type: none"> <li>• fundamental non-equilibrium theories (hydrodynamic transport theories, kinetic theories, dynamic density functional theory, stochastic descriptions, and Ito's stochastic calculus)</li> <li>• coarse-graining methods (lattice-based, moment expansion, Mori-Zwanzig, ...)</li> <li>• analytical techniques (stability analysis, partial equilibria, multi-scale perturbation theories)</li> <li>• simulations techniques (lattice gas automaton, Monte-Carlo, agent-based, stochastic particle dynamics, stochastic rotational dynamics, ...),</li> <li>• discretization methods (Gillespie, spectral method, finite differences, finite elements)</li> <li>• programming in Python and/or C++</li> </ul> Students will learn the following soft skills: <ul style="list-style-type: none"> <li>• Students learn how to apply theoretical concepts from non-equilibrium thermodynamics</li> <li>• They get trained to establish links between theoretical concepts and modern research problems</li> <li>• They will build links between lecture and textbook knowledge and applied research question, providing excellent preparation for Master's and Ph.D. research in theoretical physics</li> <li>• Students learn how to work in teams</li> <li>• They get trained in autonomous working with scientific literature in English, improving written and spoken English during lectures and exercises,</li> <li>• Students get stimulated to develop interdisciplinary thinking, and working</li> </ul>	
<b>Remarks:</b> It may be helpful if the students have participated or are simultaneously participating in one of the following Master's courses: "Non-equilibrium Statistical Physics" and "Introduction to Stochastic Processes". Please note that this is not a prerequisite since there will be introductory lectures before the application sessions.	
<b>Workload:</b> Total: 240 h 60 h studying of course content (self-study) 60 h studying of course content through exercises / case studies (self-study) 90 h lecture and exercise course (attendance) 30 h exam preparation (self-study)	
<b>Conditions:</b> Pronounced interest in theoretical physics and Statistical Physics	<b>Credit Requirements:</b> Bestehen der Modulprüfung

<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics****Mode of Instruction:** lecture**Language:** English / German**Contact Hours:** 2**Contents:**

see above

**Literature:**

- **Non-Equilibrium Thermodynamics**, S. R. De Groot and P. Mazur, Dover Publications, Dover ed edition, ISBN 486647412
- **From Macrophysics to Microphysics Part 1 und 2**, Roger Balian, Springer, ISBN 3540454780
- **Principles of Condensed Matter Physics**, P. M. Chaikin and T. C. Lubensky, Cambridge, ISBN 521794501
- **A Kinetic View of Statistical Physics**, Pavel L. Krapivsky, Sidney Redner, and Eli Ben-Naim, Cambridge, ISBN 486647412
- **Basic Concepts for Simple and Complex Liquids**, Jean-Louis Barrat and Jean-Pierre Hansen, Cambridge, ISBN 521789532
- **Physical Hydrodynamics**, Etienne Guyon, Jean-Pierre Hulin, Luc Petit, Catalin D. Mitescu, Oxford, ISBN 521851033
- **Stochastic Processes in Physics and Chemistry**, N. G. Van Kampen, North Holland, ISBN 444529659
- **Stochastic Methods: A Handbook for the Natural and Social Sciences**, Gardiner, Springer, ISBN 3540707123
- **Thinking Probabilistically: Stochastic Processes, Disordered Systems, and Their Applications**, Ariel Amir, Cambridge University Press, ISBN 1108479529
- **Statistical Physics of Fields**, Mehran Kardar, Cambridge, ISBN 052187341X

**Assigned Courses:****Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics** (lecture)**Part of the Module: Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics (Practical Course)****Mode of Instruction:** exercise course**Language:** English / German**Contact Hours:** 4**Assigned Courses:****Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics (Practical Course)**  
(exercise course)**Examination****PHM-0363 Method Course: Applying Theoretical Concepts from Non-equilibrium Statistical Physics**

oral exam / length of examination: 1 hours, graded

<b>Module PHM-0147: Method Course: Electron Microscopy</b> <i>Method Course: Electron Microscopy</i>		8 ECTS/LP
Version 1.3.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Scanning electron microscopy (SEM) <ul style="list-style-type: none"> <li>• Electron optical components</li> <li>• Detectors</li> <li>• EDX, EBSD</li> </ul> Transmission electron microscopy (TEM) <ul style="list-style-type: none"> <li>• Diffraction</li> <li>• Contrast mechanisms</li> <li>• High resolution EM</li> <li>• Scanning TEM</li> <li>• Analytical TEM</li> <li>• Aberration correction</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• get introduced to the basics of scanning electron microscopy and transmission electron microscopy, using lectures to teach the theoretical basics, which are afterwards deepened using practical courses,</li> <li>• are able to operate SEM and TEM on a basic level</li> <li>• are able to characterize materials using different electron microscopy techniques</li> <li>• Acquire the competence to decide about a technique feasible for a certain problem.</li> <li>• acquire the competence to assess EM images, also regarding artefacts</li> <li>• learn to search for scientific literature and to formulate a scientific report</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 150 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: knowledge of solid-state physics, reciprocal lattice		<b>Credit Requirements:</b> regular participation, oral presentation (10 min), written report (one report per group)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Electron Microscopy</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

**Contents:****SEM:**

1. Layout of Electron Microscopes and Electron Optical Components
2. Electron Solid Interactions
3. Contrast Formation in Scanning Electron Microscopy (SEM)
4. SE/BSE contrast
5. Electron Back Scattering Diffraction (EBSD)
6. Analytical techniques
7. Special Applications of SEM

**TEM:**

1. TEM specimen preparation techniques
2. Components of a TEM, principle lens design, lens aberrations
3. Electron diffraction: fundamentals
4. Contrast formation at bright field, dark field, weak beam dark field, and many beam conditions, „chemical“ imaging
5. Bright field, dark field, weak beam dark field imaging of dislocations
6. Kinematical theory of electron wave propagation in crystals
7. Howie Whelan equations, contrast of defects
8. High resolution TEM, lattice imaging of crystals
9. Advanced diffraction techniques: Kikuchi patterns, HOLZ lines and Convergent Beam Diffraction (CBED)
10. Image simulation
11. Analytical TEM: Electron energy loss spectroscopy & energy filtered TEM

**Literature:**

- D.B.Williams and C.B.Carter, Transmission Electron Microscopy, Plenum Press, New York/London, 1996
- M.A. Hirsch, A. Howie, R. Nicholson, D.W. Pashley, M.J. Whelan, Electron microscopy of thin crystals, Krieger Publishing Company, Malabar (Florida), 1977
- L. Reimer, Transmission electron microscopy, Springer Verlag, Berlin/Heidelberg/New York, 1984
- P.J. Goodhew, Thin foil preparation for electron microscopy, Elsevier, Amsterdam, 1985
- P.R. Buseck, J.M. Cowley, L. Eyring, High-resolution transmission electron microscopy, Oxford University Press, 1988
- E. Hornbogen, B. Skrotzki, Werkstoff-Mikroskopie, Springer Verlag, Berlin/Heidelberg/New York, 1995
- K. Wetzig, In situ scanning electron microscopy in materials research, Akad.-Verl., 1995
- J. I. Goldstein, Scanning electron microscopy and x-ray microanalysis, Plenum Press, 1992
- L. Reimer, Scanning electron microscopy, Springer Verlag, 1985
- S. L. Flegler, J. W. Heckman, K. L. Klomparens, Elektronenmikroskopie, Spektrum, Akad. Verl., 1995

**Part of the Module: Method Course: Electron Microscopy (Practical Course)****Mode of Instruction:** laboratory course**Language:** English**Contact Hours:** 4**Examination****Method Course: Electron Microscopy**

report, graded

**Examination Prerequisites:**

Method Course: Electron Microscopy

<b>Module PHM-0146: Method Course: Electronics for Physicists and Materials Scientists</b> <i>Method Course: Electronics for Physicists and Materials Scientists</i>		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering</li> <li>2. Quadrupole theory</li> <li>3. Analog technique, transistor and opamp circuits</li> <li>4. Boolean algebra and logic</li> <li>5. Digital electronics and calculation circuits</li> <li>6. Microprocessors and Networks</li> <li>7. Basics in Electronic</li> <li>8. Implementation of transistors</li> <li>9. Operational amplifiers</li> <li>10. Digital electronics</li> <li>11. Practical circuit arrangement</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the laboratory,</li> <li>• have skills in easy circuit design, measuring and control technology, analog and digital electronics,</li> <li>• have expertise in independent working on circuit problems. They can calculate and develop easy circuits.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b> Attendance in the <b>Method Course: Electronics for Physicists and Materials Scientists (combined lab course AND lecture)</b> excludes credit points for the lecture <b>Electronics for Physicists and Materials Scientists</b> .		
<b>Workload:</b> Total: 240 h 140 h studying of course content using provided materials (self-study) 60 h lecture (attendance) 10 h preparation of written term papers (self-study) 30 h internship / practical course (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> written report (one per group)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		

**Literature:**

- Paul Horowitz: The Art of Electronics (Cambridge University Press)
- National Instruments: MultiSim software package (available in lecture)

**Assigned Courses:**

**Method Course: Electronics for Physicists and Materials Scientists** (lecture)

**Part of the Module: Method Course: Electronics for Physicists and Materials Scientists (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 2

**Assigned Courses:**

**Method Course: Electronics for Physicists and Materials Scientists (Practical Course)** (internship)

**Examination**

**Method Course: Electronics for Physicists and Materials Scientists**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

each semester



<b>Module PHM-0172: Method Course: Functional Silicate-analogous Materials</b> <i>Method Course: Functional Silicate-analogous Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> Synthesis and characterization of functional materials according to the topics: <ol style="list-style-type: none"> <li>1. Silicate-analogous compounds</li> <li>2. Luminescent materials / phosphors</li> <li>3. Pigments</li> <li>4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students will know how to: <ul style="list-style-type: none"> <li>• develop functional materials based on silicate-analogous materials,</li> <li>• apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),</li> <li>• work under non-ambient atmospheres (e.g. reducing, inert conditions),</li> <li>• solve and refine crystal structures from single-crystal data,</li> <li>• describe and classify these structures properly.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 120 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: attendance to the lecture "Advanced Solid State Materials"		<b>Credit Requirements:</b> written report (protocol)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 6		

**Learning Outcome:**

The students will know how to:

- develop functional materials based on silicate-analogous materials,
- apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),
- work under non-ambient atmospheres (e.g. reducing, inert conditions),
- solve and refine crystal structures from single-crystal data,
- describe and classify these structures properly.

**Contents:**

Synthesis and characterization of functional materials according to the topics:

1. Silicate-analogous compounds
2. Luminescent materials / phosphors
3. Pigments
4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis

**Examination**

**Method Course: Functional Silicate-analogous Materials**

seminar, graded

**Examination Prerequisites:**

Method Course: Functional Silicate-analogous Materials

<b>Module PHM-0148: Method Course: Optical Properties of Solids</b> <i>Method Course: Optical Properties of Solids</i>		8 ECTS/LP
Version 1.4.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
<b>Contents:</b> Electrodynamics of solids <ul style="list-style-type: none"> <li>• Maxwell equations</li> <li>• Electromagnetic waves</li> <li>• Refraction and interference, Fresnel equations</li> </ul> FTIR spectroscopy <ul style="list-style-type: none"> <li>• Fourier transformation</li> <li>• Michelson-Morley and Genzel interferometer</li> <li>• Sources and detectors</li> </ul> Terahertz Time Domain spectroscopy <ul style="list-style-type: none"> <li>• Generation of pulsed THz radiation</li> <li>• Gated detection, Austin switches</li> </ul> Elementary excitations in solid materials <ul style="list-style-type: none"> <li>• Rotational-vibrational bands</li> <li>• Infrared-active phonons</li> <li>• Interband excitations</li> <li>• Crystal-field excitations</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic principles of far-infrared spectroscopy and terahertz time-domain-spectroscopy,</li> <li>• The students know about fundamental optical excitations in condensed matter materials that can be studied by these spectroscopic methods,</li> <li>• The students obtain the competence to plan and carry out complex experiments,</li> <li>• The students have the skills to evaluate and analyze optical data.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Remarks:</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 90 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge in solid-state physics, basic knowledge in electrodynamics and optics		<b>Credit Requirements:</b> written report
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module**

**Part of the Module: Method Course: Optical Properties of Solids**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 2

**Literature:**

Mark Fox, Optical Properties of Solids, Oxford Master Series

Eugene Hecht, Optics, Walter de Gruyter

**Part of the Module: Method Course: Optical Properties of Solids (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Examination**

**Method Course: Optical Properties of Solids**

report, graded

**Examination Prerequisites:**

Method Course: Optical Properties of Solids

<b>Module PHM-0149: Method Course: Methods in Biophysics</b> <i>Method Course: Methods in Biophysics</i>		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Dr. Christoph Westerhausen		
<b>Contents:</b> Unit Membrane biophysics <ul style="list-style-type: none"> <li>• Preparation of synthetic lipid membranes</li> <li>• Size, fluorescence and phase transition characterization of lipid membranes</li> <li>• Nanoparticle uptake synthetic membrane</li> </ul> Unit microfluidic <ul style="list-style-type: none"> <li>• Microfluidic systems</li> <li>• Fabrication of microfluidic systems</li> <li>• Calculation of microfluidic problems</li> </ul> Unit live cell experiments <ul style="list-style-type: none"> <li>• Cell culture</li> <li>• Cell coating and separation using microfluidics</li> </ul> Unit analysis		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know basic terms, concepts and phenomena in biophysics</li> <li>• acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic manipulation and analysis systems,</li> <li>• learn skills in tissue culture and immun-histochemical staining procedures,</li> <li>• learn skills in fluorescence microscopy,</li> <li>• learn skills to calculate fluidic problems on small length scales,</li> <li>• learn skills to handle microfluidic channel systems.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Attendance of the lecture "Biophysics and Biomaterials"		<b>Credit Requirements:</b> 1 written lab report
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Methods in Biophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

**Part of the Module: Method Course: Methods in Biophysics (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Literature:**

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle und R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- Lecture notes

**Examination**

**Method Course: Methods in Biophysics**

report, graded

**Examination Prerequisites:**

Method Course: Methods in Biophysics

<b>Module PHM-0153: Method Course: Magnetic and Superconducting Materials</b> <i>Method Course: Magnetic and Superconducting Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> Methods of growth and characterization: Sample preparation (bulk materials and thin films), e.g., <ul style="list-style-type: none"> <li>• arc melting</li> <li>• flux-growth</li> <li>• sputtering and evaporation</li> </ul> Sample characterization, e.g., <ul style="list-style-type: none"> <li>• X-ray diffraction</li> <li>• electron microscopy, scanning tunneling microscopy</li> <li>• magnetic susceptibility, electrical resistivity</li> <li>• specific heat</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• get to know the basic methods of materials growth and characterization, such as poly- and single crystal growth, thin-film growth, X-ray diffraction, magnetic susceptibility, dc-conductivity, and specific heat measurements</li> <li>• are trained in planning and performing complex experiments</li> <li>• learn to evaluate and analyze the collected data, are taught to work on problems in experimental solid state physics, including analysis of measurement results and their interpretation in the framework of models and theories</li> </ul>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics and quantum mechanics		<b>Credit Requirements:</b> presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Magnetic and Superconducting Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

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**Part of the Module: Method Course: Magnetic and Superconducting Materials (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Examination**

**Method Course: Magnetic and Superconducting Materials**

report, graded

**Examination Prerequisites:**

Method Course: Magnetic and Superconducting Materials



<b>Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy</b> <i>Method Course: Modern Solid State NMR Spectroscopy</i>		8 ECTS/LP
Version 2.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
<b>Contents:</b> Physical foundations of NMR spectroscopy Internal interactions in NMR spectroscopy <ul style="list-style-type: none"> <li>• Chemical shift interaction</li> <li>• Dipole interaction and</li> <li>• Quadrupolar interaction</li> </ul> Magic Angle Spinning techniques Modern applications of NMR in materials science Experimental work at the Solid-State NMR spectrometers, computer-aided analysis and interpretation of acquired data		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• gain basic knowledge of the physical foundations of modern Solid-State NMR spectroscopy,</li> <li>• gain basic practical knowledge of operating a solid-state NMR spectrometer,</li> <li>• can -- under guidance -- plan, perform, and analyze modern solid-state NMR experiments for the structural characterization of advanced materials.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
<b>Conditions:</b> The attendance of the lecture "NOVEL METHODS IN SOLID STATE NMR SPECTROSCOPY" is highly recommended.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Modern Solid State NMR Spectroscopy</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 2		

**Literature:**

- M. H. Levitt, spin Dynamics, John Wiley and Sons, Ltd., 2008.
- H. Günther NMR spectroscopy, Wiley, 2001.
- M. Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
- D. Canet, NMR - concepts and methods, Springer, 1994.

**Part of the Module: Method Course: Modern Solid State NMR Spectroscopy (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Literature:**

1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008.
2. H. Günther, NMR spectroscopy, Wiley 2001.
3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
4. D. Canet: NMR - concepts and methods, Springer, 1994.

**Examination**

**Method Course: Modern Solid State NMR Spectroscopy**

report / work period for assignment: 2 weeks, graded

**Examination Prerequisites:**

Method Course: Modern Solid State NMR Spectroscopy

<b>Module PHM-0206: Method Course: Infrared Microspectroscopy under Pressure</b> <i>Method Course: Infrared Microspectroscopy under Pressure</i>		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Christine Kuntscher		
<p><b>Contents:</b></p> <p>Electrodynamics of solids</p> <p>Maxwell equations and electromagnetic waves in matter</p> <p>Optical variables</p> <p>Theories for dielectric function:</p> <p>i. Free carriers in metals and semiconductors (Drude)</p> <p>ii. Interband absorptions in semiconductors and insulators</p> <p>iii. Vibrational absorptions</p> <p>iv. Multilayer systems</p> <p>FTIR microspectroscopy</p> <p>Components of FTIR spectrometers</p> <p>i. Light sources</p> <p>ii. Interferometers</p> <p>iii. Detectors</p> <p>Microscope components</p> <p>High pressure experiments Equipments</p> <p>Pressure calibration</p> <p>Experimental techniques under high pressure</p> <p>i. IR spectroscopy</p> <p>ii. Raman scattering</p> <p>iii. Magnetic measurements</p> <p>iv. Transport measurements</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students</p> <p>Learn about the basics of the light interaction with various materials and the fundamentals of FTIR microspectroscopy,</p> <p>Are introduced to the high pressure equipments used in infrared spectroscopy,</p> <p>Learn to carry out infrared microspectroscopy experiments under pressure,</p> <p>Learn to analyze the measured optical spectra.</p>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Written report
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Infrared Microspectroscopy under Pressure</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Assigned Courses:</b> <b>Method Course: Infrared Microspectroscopy under Pressure</b> (lecture)
<b>Part of the Module: Method Course: Infrared Microspectroscopy under Pressure (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Method Course: Infrared Microspectroscopy under Pressure (Practical Course)</b> (internship)
<b>Examination</b> <b>Method Course: Infrared Microspectroscopy under Pressure</b> report, graded

<b>Module PHM-0216: Method Course: Thermal Analysis</b> <i>Method Course: Thermal Analysis</i>		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Ferdinand Haider Dr. Robert Horny		
<b>Contents:</b> Methods of thermal analysis: - Differential Scanning Calorimetry: DSC, DTA - Thermo-gravimetric Analysis: TGA - Dilatometry: DIL - Dynamic-mechanical Analysis: DMA -Rheology: RHEO Advanced Methods: - Modulated Differential Scanning Calorimetry: MDSC - Evolved Gas Analysis: EGA (GCMS, FTIR)		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• get to know the basic principles of thermal analysis</li> <li>• learn about fundamental thermal processes in condensed matter ,e.g. phase transitions and relaxation processes (metals, polymers, ceramics)</li> <li>• learn to plan and carry out complex experiments and the usage of advanced measurement techniques</li> <li>• learn how to evaluate and analyze thermal data</li> <li>• are aware of common raw data artefacts leading to misinterpretation</li> </ul>		
<b>Remarks:</b>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 30 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in solid-state physics		<b>Credit Requirements:</b> regular participation, oral presentation (10 min), written report
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Thermal Analysis</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Ferdinand Haider <b>Language:</b> English <b>Contact Hours:</b> 2		

**Literature:**

- Differential scanning calorimetry, Höhne, Hemminger, Flammersheim, H., Springer, 2003
- Practical Gas Chromatography, Dettmer-Wilde, Engewald, Springer, 2014
- Das Rheologie-Handbuch, Mezger, Vincentz, 2010

**Assigned Courses:**

**Method Course: Thermal Analysis** (course)

**Part of the Module: Method Course: Thermal Analysis (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Assigned Courses:**

**Method Course: Thermal Analysis** (course)

**Examination**

**Method Course: Thermal Analysis**

report, graded

<b>Module PHM-0224: Method Course: Theoretical Concepts and Simulation</b> <i>Method Course: Theoretical Concepts and Simulation</i>		8 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Liviu Chioncel		
<b>Contents:</b> This module covers Monte-Carlo methods (computational algorithms) for classical and quantum problems. Python as programming language will be employed. The following common applications will be discussed: <ul style="list-style-type: none"> <li>• Monte-Carlo integration, stochastic optimization, inverse problems</li> <li>• Feynman path integrals: the connection between classical and quantum systems</li> <li>• Order and disorder in spin systems, fermions, and boson</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are capable of obtaining numerical solutions to problems too complicated to be solved analytically</li> <li>• The students are able to present (graphically), discuss and analyze the results</li> <li>• The students gain experience in formulating and carrying out a collaborative project</li> </ul>		
<b>Remarks:</b> The number of students will be limited to 8.		
<b>Workload:</b> Total: 240 h 90 h preparation of presentations (self-study) 60 h preparation of written term papers (self-study) 60 h studying of course content (self-study) 90 h (attendance)		
<b>Conditions:</b> Knowledge of the programming language Python is expected on the level taught in the modul PHM-0041. Requirements to understand basic concepts in physics: Classical Mechanics (Newton, Lagrange), Electrodynamics, Thermodynamics and Quantum Mechanics.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Theoretical Concepts and Simulation</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2
<b>Contents:</b> Concepts of classical and quantum statistical physics: <ul style="list-style-type: none"> <li>• the meaning of sampling, random variables, ergodicity</li> <li>• equidistribution, pressure, temperature</li> <li>• path integrals, quantum statistics, enumeration, cluster algorithms</li> </ul>
<b>Literature:</b> <ol style="list-style-type: none"> <li>1. Werner Krauth, Algorithms and Computations (Oxford University Press, 2006)</li> <li>2. R. H. Landau, A Survey of Computational Physics (Princeton Univ. Press, 2010)</li> </ol>

**Part of the Module: Method Course: Theoretical Concepts and Simulation (Practical Course)**

**Mode of Instruction:** internship

**Language:** English / German

**Contact Hours:** 4

**Contents:**

see above

**Literature:**

see above

**Examination**

**Method Course: Theoretical Concepts and Simulation**

report / work period for assignment: 4 weeks, graded

**Description:**

The requirement for the credit points is based on a programming project carried out in a team of 2-3 students. The final report contains the formulation and a theoretical introduction into the problem, the numerical implementation, and the presentation of the results.



<b>Module PHM-0223: Method Course: Tools for Scientific Computing</b> <i>Method Course: Tools for Scientific Computing</i>	8 ECTS/LP
Version 1.6.0 (since SoSe18) Person responsible for module: Prof. Dr. Gert-Ludwig Ingold	
<b>Contents:</b> Important tools for scientific computing are taught in this module and applied to specific scientific problems by the students. As far as tools depend on a particular programming language, Python will be employed. Tools to be discussed include: <ul style="list-style-type: none"> <li>• numerical libraries like NumPy and SciPy</li> <li>• visualisation of numerical results</li> <li>• use of a version control system like git and its application in collaborative work</li> <li>• testing of code</li> <li>• profiling</li> <li>• documentation of programs</li> </ul>	
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are capable of solving a physical problem of some complexity by means of numerical techniques. They are able to visualize the results and to adequately document their program code.</li> <li>• The students know examples of numerical libraries and are able to apply them to solve scientific problems.</li> <li>• The students know methods for quality assurance like the use of unit tests and can apply them to their code. They know techniques to identify run-time problems.</li> <li>• The students know a distributed version control system and are able to use it in a practical problem.</li> <li>• The students have gained practical experience in a collaborative project work. They are able to plan and carry out a programming project in a small group.</li> <li>• The students understand the relevance of the tools taught in the method course for good scientific practice.</li> </ul>	
<b>Remarks:</b> The number of students will be limited to 12.	
<b>Workload:</b> Total: 240 h 60 h studying of course content (self-study) 90 h (attendance) 30 h preparation of presentations (self-study) 60 h preparation of written term papers (self-study)	
<b>Conditions:</b> Knowledge of the programming language Python is expected on the level taught in the module PHM-0243 "Einführung in Prinzipien der Programmierung".	<b>Credit Requirements:</b> The module examination needs to be passed which is based on a scientific programming project carried out in a small team of 2-3 students. The work will be judged on the basis of a joint final report and the contributions of the individual students as documented in the team's Gitlab project. The final report should contain an explanation of the scientific problem and its numerical implementation as well as a presentation of results. The code should be appropriately documented and tested.

<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Method Course: Tools for Scientific Computing****Mode of Instruction:** lecture**Language:** English / German**Contact Hours:** 2**Learning Outcome:**

- The students know the numerical libraries NumPy and SciPy and selected tools for the visualization of numerical results.
- The students know fundamental techniques for the quality assurance of programs like the use of unit tests, profiling and the use of the version control system git. They are able to adequately document their code.
- The students understand the relevance of the tools taught in the method course for good scientific practice.

**Contents:**

- numerical libraries NumPy and SciPy
- graphics with matplotlib
- version control system Git and workflow for Gitlab/Github
- unit tests
- profiling
- documentation using docstrings and Sphinx

**Literature:**

- A. Scopatz, K. D. Huff, *Effective Computation in Physics* (O'Reilly, 2015)
- lecture notes are freely available at <https://gertingold.github.io/tools4scicomp>

**Part of the Module: Method Course: Tools for Scientific Computing (Practical Course)****Mode of Instruction:** internship**Language:** English / German**Contact Hours:** 4**Learning Outcome:**

- The students are capable of solving a physical problem of some complexity by means of numerical techniques and to visualize the results.
- They have gained some experience in the application of methods for quality assurance of their code and are able to appropriately document their programs.
- The students are able to work in a team and know how to make use of tools like Gitlab/Github.
- The students are able to present the status of their work, to critically assess it and to accept suggestions from others.

**Contents:**

The tools discussed in the lecture will be applied to specific scientific problems by small teams of 2-3 students under supervision. The teams regularly inform the other teams in oral presentations on their progress, the tools employed as well as encountered problems and their solution.

**Examination**

**Method Course: Tools for Scientific Computing**

report / work period for assignment: 4 weeks, graded

**Test Frequency:**

when a course is offered

**Description:**

The requirement for credit points is based on a scientific programming project carried out in a small team of 2-3 students. The work will be judged on the basis of a joint final report and the contributions of the individual students as documented in the team's Gitlab project. The final report should contain an explanation of the scientific problem and its numerical implementation as well as a presentation of results. The code should be appropriately documented and tested.

<b>Module PHM-0258: Method course: Charge doping effects in semiconductors</b> <i>Method course: Charge doping effects in semiconductors</i>		8 ECTS/LP
Version 1.0.0 (since SoSe21) Person responsible for module: Prof. Dr. István Kézsmárki Dr. Lilian Prodan, Dr. Somnath Ghara		
<b>Contents:</b> The goal of the method course is to make students familiar with the concept of controlling the type and the concentration of charge carriers in semiconductors, which is widely used approach in electronics and various fields of materials science. For this purpose, the current method course will be dealing with the preparation of various electron-doped and / or hole-doped narrow-gap semiconductors and investigation of the influence of charge doping on transport and magnetic properties. The following techniques will be involved: <ul style="list-style-type: none"> <li>• Synthesis of electron and hole doped narrow-gap semiconductors, such as Zn- and Ge-doped GaV4S8, in polycrystalline forms using solid state reaction;</li> <li>• Refining the structure and checking phase purity by X-ray powder diffraction;</li> <li>• Resistivity and magneto-transport measurements;</li> <li>• Hall effect measurements to quantify carrier concentration;</li> <li>• Investigation of the doping-induced changes in the magnetic properties by magnetization measurements.</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students gain basic knowledge how to tailor the bulk properties of narrow-gap semiconductors via different doping techniques.</li> <li>• The students have detailed knowledge in performing XRD and magnetization experiments and know how to analyze the data.</li> <li>• The students acquire the competence to plan and perform Hall effect and magnetoresistance experiments and evaluate the obtained experimental results.</li> <li>• The students have the skill to distinguish between an n-type and p-type semiconductor.</li> <li>• The students know how to calculate the charge, mobility, and charge carrier density of a semiconductor using information obtained from the Hall effect experiments.</li> </ul>		
<b>Remarks:</b> ELECTIVE COMPULSORY MODULES		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics and semiconductors;		<b>Credit Requirements:</b> Written report on the experiments (editing time 2 weeks)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method course: Charge doping effects in semiconductors (Practical Course)</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Contact Hours:</b> 4		

**Contents:**

The following techniques will be involved:

- Synthesis of electron and hole doped narrow-gap semiconductors, such as Zn- and Ge-doped GaV4S8, in poly-crystalline forms using solid state reaction;
- Refining the structure and checking phase purity by X-ray powder diffraction;
- Resistivity and magneto-transport measurements;
- Hall effect measurements to quantify carrier concentration;
- Investigation of the doping-induced changes in the magnetic properties by magnetization measurements.

**Assigned Courses:**

**Method Course: Charge doping effects in semiconductors** (lecture)

**Part of the Module: Method course: Charge doping effects in semiconductors**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 2

**Learning Outcome:**

The goal of the method course is to make students familiar with the concept of controlling the type and the concentration of charge carriers in semiconductors, which is widely used approach in electronics and various fields of materials science. For this purpose, the current method course will be dealing with the preparation of various electron-doped and / or hole-doped narrow-gap semiconductors and investigation of the influence of charge doping on transport and magnetic properties.

**Assigned Courses:**

**Method Course: Charge doping effects in semiconductors** (lecture)

**Examination**

**Method course: Charge doping effects in semiconductors**  
report, graded

<b>Module PHM-0285: Method Course: Computational Biophysics</b> <i>Method Course: Computational Biophysics</i>		8 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Nadine Schwierz-Neumann		
<b>Contents:</b> Life relies on the interactions of proteins, nucleic acids, lipids and other biomolecules. This course introduces computational methods to study the structure, dynamics and mechanics of these biomolecules. In the first part of the course, the physics behind biomolecular simulations is explained and the basic principles of classical and statistical mechanics are reviewed. In the second part, different simulation techniques are introduced including molecular dynamics simulations and Monte Carlo simulations. Subsequently the methods are applied to biological systems consisting of proteins, nucleic acids and lipids		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Students develop an active understanding of the principles, the capacity and limitations of biomolecular simulations</li> <li>• Students learn to solve typical biophysical problems analytically and numerically</li> <li>• Students learn how to run and analyze computer simulations of biological matter</li> <li>• Students learn to visualize, document and present their simulation results</li> </ul>		
<b>Remarks:</b> Number of students will be limited to 15.		
<b>Workload:</b> Total: 240 h 90 h exam preparation (self-study) 60 h studying of course content (self-study) 90 h (attendance)		
<b>Conditions:</b> Knowledge of classical mechanics on the bachelor level is expected.		<b>Credit Requirements:</b> Passing of the module exam
<b>Frequency:</b> every 3rd semester Ab SoSe2022	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Computational Biophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		
<b>Learning Outcome:</b> <ul style="list-style-type: none"> <li>• Theoretical background of biomolecular simulations</li> <li>• Computational methods to describe the structure, dynamics and mechanics of biomolecules</li> </ul>		

**Contents:**

- Introduction to classical mechanics in phase space
- Probability and information theory
- Connection to statistical mechanics
- Molecular dynamics basics
- Monte Carlo Simulations
- Forces and force fields in biomolecular systems
- Simulations in different ensembles
- Calculating macroscopic thermodynamic properties from simulations

**Literature:**

- Daniel M. Zuckerman, *Statistical Physics of Biomolecules* (2010 by Taylor and Francis Inc.)
- Ken Dill and Sarina Bromberg, *Molecular Driving Forces* (2012 by Taylor and Francis Inc; 2nd edition)
- Daan Frenkel and Berend Smit, *Understanding Molecular Simulation* (2002 by Elsevier, 2nd edition)

**Part of the Module: Method Course: Computational Biophysics (Practical Course)**

**Mode of Instruction:** internship

**Language:** English / German

**Contact Hours:** 4

**Learning Outcome:**

- Students learn to solve typical biophysical problems analytically and numerically
- Students learn to run and analyze computer simulations of biological matter
- Students learn to visualization, documentation and presentation of results

**Contents:**

The methods and tools discussed in the lecture will be applied to typical biophysical problems and biological systems. The students work individually or in small teams under supervision. The students present their solutions, document their simulations and summarize their results in a final report.

**Examination**

**Method Course: Computational Biophysics**

written exam / length of examination: 2 hours, graded

<b>Module PHM-0158: Introduction to Materials (= Seminar)</b> <i>Introduction to Materials</i>		4 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Varying topics for each year, giving an overview into scope, application, requirements and preparation of all types of modern materials.		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the major principles, applications and processes of modern materials,</li> <li>• acquire the competence to compile knowledge for examples of material specific topics and to present this knowledge in given time to an audience.</li> </ul>		
<b>Remarks:</b> <b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 120 h		
<b>Conditions:</b> Recommended: basic knowledge in materials science		<b>Credit Requirements:</b> regular participation, oral presentation with term paper (30 - 45 minutes)
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Introduction to Materials (Seminar)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Literature:</b> specific for each topic, to be gathered by the students

<b>Examination</b> <b>Introduction to Materials</b> presentation, graded <b>Examination Prerequisites:</b> Introduction to Materials
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<b>Module PHM-0159: Laboratory Project</b> <i>Laboratory Project</i>		10 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> Experimental or theoretical work in a laboratory / research group in the Institute of Physics. Has to be conducted within 3 months.		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, skills and concepts to pursue a real research project in the existing laboratories within the research groups,</li> <li>• experience the day to day life in a research group from within,</li> <li>• prepare themselves to conduct a research project during their Masters thesis.</li> </ul>		
<b>Remarks:</b> The Laboratory Project will be offered in SoSe 2020 as soon as the current situation allows.		
<b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 300 h		
<b>Conditions:</b> Recommended: solid knowledge in (solid state) Physics, Chemistry and Materials Science, both experimentally and theoretically		<b>Credit Requirements:</b> 1 written report (editing time 2 weeks)
<b>Frequency:</b> each semester Siehe Bemerkungen	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 0 semester[s]
<b>Contact Hours:</b> 8	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Laboratory Project</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Contact Hours:</b> 8
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Various</li> </ul>

<b>Examination</b> <b>Laboratory Project</b> project work, graded <b>Examination Prerequisites:</b> Laboratory Project
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<b>Module PHM-0057: Physics of Thin Films</b> <i>Physics of Thin Films</i>		6 ECTS/LP
Version 1.6.0 (since WS09/10) Person responsible for module: PD Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Thin film growth: basics, thermodynamic considerations, surface kinetics, growth mechanisms</li> <li>Thin film growth techniques: vacuum technology, physical vapor deposition, chemical vapor deposition</li> <li>Analysis and characterization of thin films: in-sit methods, ex-situ methods, direct methods</li> <li>Properties and applications of thin films</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>know a broad spectrum of methods of thin film technology and material properties and applications of thin films,</li> <li>have the competence to deal with current problems in the field of thin film technology largely autonomous,</li> <li>are able to choose the right substrates and thin film materials for epitaxial thin film growth to achieve desired application conditions,</li> <li>acquire skills of combining the various technologies for growing thin layers with respect to their properties and applications, and</li> <li>acquire scientific soft skills to search for scientific literature, understand technical english, work with literature in the field of thin films, interpret experimental results.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> every 3rd semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Physics of Thin Films</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 4
<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description

**Literature:**

- H. Frey, G. Kienel, Dünnschichttechnologie (VDI Verlag, 1987)
- H. Lüth, Solid Surfaces, Interfaces and Thin Films (Springer Verlag, 2001)
- A. Wagendristel, Y. Wang, An Introduction to Physics and Technology of Thin Films (World Scientific Publishing, 1994)
- M. Ohring, The Materials Science of Thin Films (Academic Press, 1992)

**Examination**

**Physics of Thin Films**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Physics of Thin Films

<b>Module PHM-0058: Organic Semiconductors</b> <i>Organic Semiconductors</i>		6 ECTS/LP
Version 1.6.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Brütting		
<b>Contents:</b> Basic concepts and applications of organic semiconductors Introduction <ul style="list-style-type: none"> <li>• Materials and preparation</li> <li>• Structural properties</li> <li>• Electronic structure</li> <li>• Optical and electrical properties</li> </ul> Devices and Applications <ul style="list-style-type: none"> <li>• Organic metals</li> <li>• Light-emitting diodes</li> <li>• Solar cells</li> <li>• Field-effect transistors</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic structural and electronic properties of organic semiconductors as well as the essential function of organic semiconductor devices,</li> <li>• have acquired skills for the classification of the materials taking into account their specific features in the functioning of components,</li> <li>• and have the competence to comprehend and attend to current problems in the field of organic electronics.</li> <li>• Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 40 h studying of course content through exercises / case studies (self-study) 40 h studying of course content using provided materials (self-study) 40 h studying of course content using literature (self-study)		
<b>Conditions:</b> It is strongly recommended to complete the module solid-state physics first. In addition, knowledge of molecular physics is desired.		
<b>Frequency:</b> Sommersemester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 5	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Organic Semiconductors</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Wolfgang Brütting <b>Language:</b> English <b>Contact Hours:</b> 3		

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)
- W. Brütting: Physics of Organic Semiconductors (Wiley-VCH)
- A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)
- S.R. Forrest: Organic Electronics (Oxford Univ. Press)

**Part of the Module: Organic Semiconductors (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 2

**Examination****Organic Semiconductors**

written exam / length of examination: 60 minutes, graded

**Examination Prerequisites:**

Organic Semiconductors

<b>Module PHM-0060: Low Temperature Physics</b> <i>Low Temperature Physics</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Properties of matter at low temperatures</li> <li>• Cryoliquids and superfluidity</li> <li>• Cryogenic engineering</li> <li>• Thermometry</li> <li>• Quantum transport, criticality and entanglement in matter</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic properties of matter at low temperatures and the corresponding experimental techniques,</li> <li>• have acquired the theoretical knowledge to perform low-temperature measurements,</li> <li>• and know how to experimentally investigate current problems in low-temperature physics.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Physik IV - Solid-state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Low Temperature Physics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		

**Contents:**

- Introduction (temperature scale, history of low temperature physics)
- Properties of matter at low temperatures (specific heat, thermal expansion, electrical resistance, thermal conductivity)
- Cryoliquids and superfluidity (nitrogen, hydrogen, 4-He and 3-He: phase diagrams, superfluidity)
- Cryogenic engineering (liquefaction of gases, helium cryostats, dilution refrigerator, adiabatic demagnetization, further techniques)
- Thermometry (primary and secondary thermometers at different temperature regimes)
- Quantum Matter (quantum Transport, Quantum phase transitions, Quantum spin liquids)

**Literature:**

C. Enss, S. Hunklinger, Tieftemperaturphysik (Springer)  
F. Pobell, Matter and Methods at Low Temperatures (Springer)

**Assigned Courses:**

**Low Temperature Physics** (lecture)

**Part of the Module: Low Temperature Physics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Assigned Courses:**

**Low Temperature Physics (Tutorial)** (exercise course)

**Examination**

**Low Temperature Physics**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Low Temperature Physics

<b>Module PHM-0066: Superconductivity</b> <i>Superconductivity</i>		6 ECTS/LP
Version 1.0.0 (since WS11/12) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introductory Remarks and Literature</li> <li>• History and Main Properties of the Superconducting State, an Overview</li> <li>• Phenomenological Thermodynamics and Electrodynamics of the SC</li> <li>• Ginzburg-Landau Theory</li> <li>• Microscopic Theories</li> <li>• Fundamental Experiments on the Nature of the Superconducting State</li> <li>• Josephson-Effects</li> <li>• High Temperature Superconductors</li> <li>• Application of Superconductivity</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• will get an introduction to superconductivity,</li> <li>• by a presentation of experimental results they will learn the fundamental properties of the superconducting state,</li> <li>• are informed about the most important technical applications of superconductivity.</li> <li>• Special attention will be drawn to the basic concepts of the main phenomeno-logical and microscopic theories of the superconducting state, to explain the experimental observations.</li> <li>• For self-studies a comprehensive list of further reading will be supplied.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Physik IV – Solid-state physics</li> <li>• Theoretical physics I-III</li> </ul>		
<b>Frequency:</b> each summer semester not in summer term 2023	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Superconductivity</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		



**Literature:**

- W. Buckel, Supraleitung, 5. Auflage (VCH, Weinheim, 1994)
- W. Buckel und R. Kleiner, Supraleitung, 6. Auflage (WILEY-VCH, Weinheim, 2004)
- M. Tinkham, Introduction to Superconductivity, 2nd Edition (McGraw-Hill, Inc., New York, 1996, Reprint by Dover Publications Inc. Miniola , 2004)
- Weitere Literatur wird in der Vorlesung angegeben

**Examination**

**Superconductivity**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Superconductivity

<b>Module PHM-0252: Optical Excitations in Materials</b> <i>Optical Excitations in Materials</i>		6 ECTS/LP
Version 1.9.0 (since SoSe20) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
<b>Contents:</b> 1. Classical Light-Matter Interaction in Solids: <ul style="list-style-type: none"> <li>• Introduction: Typical Optical Response of Metals and Semiconductors</li> <li>• Classical electromagnetic wave propagation in linear optical media (Maxwell Equations, refractive index, reflection, transmission, absorption)</li> <li>• Anisotropic media, birefringence, longitudinal solutions</li> <li>• Classical Drude-Lorentz oscillator model</li> <li>• Spectroscopic techniques: Fourier-Transform-Spectroscopy, Time-domain Spectroscopy, Ellipsometry</li> </ul> 2. Quantum Aspects of Light-Matter interaction <ul style="list-style-type: none"> <li>• qm approach to absorption and emission: Lorentzian lineshape, Fermi's Golden Rule</li> <li>• Electric-dipole and magnetic-dipole approximation</li> <li>• Rabi-oscillations and the need for quantum optical approaches</li> <li>• A glimpse of non-linear optics</li> </ul> 3. Excitations in different material classes <ul style="list-style-type: none"> <li>• Optical properties of semiconductors/insulators, molecular materials, metals</li> <li>• Absorption and Luminescence, excitons, luminescence centers</li> <li>• Optoelectronics, detectors, light emitting devices</li> <li>• Quantum confined structures: tuning of absorption and emission</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students gain basic knowledge of the fundamental concepts of light-matter interaction in solids.</li> <li>• The students have detailed knowledge of classical models of light-propagation and absorption and get the competence to choose adequate spectroscopic techniques for measuring the optical properties of different material classes.</li> <li>• The students have a basic understanding of quantum aspects of optical processes in different materials.</li> <li>• The students are able apply these concepts to understand and analyse optical properties of different materials.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic knowledge of classical electrodynamics, atomic and solid state physics.		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

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**Parts of the Module**

**Part of the Module: Optical Excitations in Materials**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 4

**ECTS Credits:** 6.0

**Literature:**

1. Mark Fox, Optical Properties of Solids, Oxford Master Series
2. Mark Fox, Quantum Optics: An Introduction, Oxford Master Series
3. David B. Tanner, Optical Effects in Solids, Cambridge University Press
4. Y. Toyozawa, Optical Processes in Solids, Cambridge University Press

**Assigned Courses:**

**Optical Excitations in Materials** (lecture)

**Examination**

**Optical Excitations in Materials**

written exam / length of examination: 90 minutes, graded

<b>Module PHM-0253: Dielectric Materials</b> <i>Dielectric Materials</i>		6 ECTS/LP
Version 2.0.0 (since SoSe23) Person responsible for module: PD Dr. Peter Lunkenheimer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Experimental techniques: quantities, broadband dielectric spectroscopy, nonlinear and polarization measurements</li> <li>• Dynamic processes in dielectric materials: relaxation processes, phenomenological models</li> <li>• Dielectric properties of disordered matter: liquids, glasses, plastic crystals</li> <li>• Charge transport: hopping conductivity, universal dielectric response</li> <li>• Ionic conductivity: conductivity mechanism, dielectric properties, advanced electrolytes for energy-storage devices</li> <li>• Maxwell-Wagner relaxations: equivalent-circuits, applications (supercapacitors), colossal-dielectric-constant materials</li> <li>• Electroceramics: Materials, Properties (relaxor ferroelectric, ferroelectric, antiferroelectric and multiferroic), Applications</li> </ul>		
<b>Learning Outcomes / Competences:</b> Students know the fundamentals of electromagnetic wave propagation and have a sound background for a broad spectrum of dielectric phenomena. They are able to analyze materials requirements and to interpret dielectric spectra in a broad frequency range. They have the competence to select materials for different kinds of applications and to critically assess experimental results on dielectric properties.		
<b>Remarks:</b> <b>Elective compulsory module</b>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic knowledge of solid state physics		<b>Credit Requirements:</b> Pass of module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Dielectric Materials</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> PD Dr. Peter Lunkenheimer <b>Language:</b> English / alle Sprachen		

**Literature:**

- F. Kremer and A. Schönhal (eds.), Broadband Dielectric Spectroscopy (Springer, Berlin, 2002).
- F. Kremer and A. Loidl (eds.), The scaling of relaxation processes (Springer, Cham, 2018).
- A.K. Jonscher, Dielectric Relaxations in Solids (Chelsea Dielectrics Press, London, 1983).
- C.J.F. Böttcher and P. Bordewijk, Theory of electric polarisation Vol II (Elsevier, Amsterdam, 1973).
- S.R. Elliott, Physics of Amorphous Materials (Longman, London, 1990)
- A.J. Moulson, J.M. Herbert, Electroceramics: Materials, Properties, Applications (Wiley, 2003)
- R. Waser, U. Böttger, S. Tiedke, Polar Oxides: Properties, Characterization, and Imaging (Wiley, 2005)

**Examination**

**Dielectric Materials Dielectric Materials**

presentation / length of examination: 45 minutes, graded

**Examination Prerequisites:**

Dielectric Materials

<b>Module PHM-0051: Biophysics and Biomaterials</b> <i>Biophysics and Biomaterials</i>		6 ECTS/LP
Version 1.1.0 (since SoSe22) Person responsible for module: Dr. Stefan Thalhammer Westerhausen, Christoph, Dr.		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Transcription and translation</li> <li>• Membranes</li> <li>• DNA and proteins</li> <li>• Enabling technologies</li> <li>• Microfluidics</li> <li>• Radiation Biophysics</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students know: <ul style="list-style-type: none"> <li>• basic terms, concepts and phenomena of biological physics</li> <li>• models of the (bio)polymer-theory, microfluidics, radiation biophysics, nanobiotechnology, sequencing strategies, membranes and proteins</li> </ul> The students obtain skills <ul style="list-style-type: none"> <li>• for independent processing of problems and dealing with current literature.</li> <li>• to translate a biological observation into a physical question.</li> </ul> The students improve the key competences: <ul style="list-style-type: none"> <li>• self-dependent working with English specialist literature.</li> <li>• processing and interpretation of experimental data.</li> <li>• interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study)		
<b>Conditions:</b> Mechanics, Thermodynamics, Statistical Physics		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Biophysics and Biomaterials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Learning Outcome:**

See module description.

**Contents:**

- Radiation Biophysics
  - Radiation sources
  - Interaction of radiation with biological matter
  - Radiation protection principles
  - Low dose radiation
  - LNT model in radiation biophysics
- Microfluidics
  - Life at Low Reynolds Numbers
  - The Navier-Stokes Equation
  - Low Reynolds Numbers – The Stokes Equation
  - Breaking the Symmetry
- Membranes
  - Thermodynamics and Fluctuations
  - Thermodynamics of Interfaces
  - Phase Transitions – 2 state model
  - Lipid membranes and biological membranes, membrane elasticity
- Membranal transport
  - Random walk, friction and diffusion
  - Transmembranal ionic transport and ion channels
  - Electrophysiology of cells
  - Neuronal Dynamics

**Literature:**

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle, R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- lecture notes

**Part of the Module: Biophysics and Biomaterials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

See module description.

**Examination****Biophysics and Biomaterials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Biophysics and Biomaterials

<b>Module PHM-0059: Magnetism</b> <i>Magnetism</i>		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Dr. Hans-Albrecht Krug von Nidda		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• History, basics</li> <li>• Magnetic moments, classical and quantum phenomenology</li> <li>• Exchange interaction and mean-field theory</li> <li>• Magnetic anisotropy and magnetoelastic effects</li> <li>• Thermodynamics of magnetic systems and applications</li> <li>• Magnetic domains and domain walls</li> <li>• Magnetization processes and micro magnetic treatment</li> <li>• AC susceptibility and ESR</li> <li>• Spintransport / spintronics</li> <li>• Recent problems of magnetism</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic properties and phenomena of magnetic materials and the most important methods and concepts for their description, like mean-field theory, exchange interactions and micro magnetic models,</li> <li>• have the ability to classify different magnetic phenomena and to apply the corresponding models for their interpretation, and</li> <li>• have the competence independently to treat fundamental and typical topics and problems of magnetism.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> basics of solid-state physics and quantum mechanics		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Magnetism</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		



**Literature:**

- D. H. Martin, Magnetism in Solids (London Iliffe Books Ltd.)
- J. B. Goodenough, Magnetism and the Chemical Bond (Wiley)
- P. A. Cox, Transition Metal Oxides (Oxford University Press)
- C. Kittel, Solid State Physics (Wiley)
- D. C. Mattis, The Theory of Magnetism (Wiley)
- G. L. Squires, Thermal Neutron Scattering (Dover Publications Inc.)

**Part of the Module: Magnetism (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Magnetism**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Magnetism

<b>Module PHM-0048: Physics and Technology of Semiconductor Devices</b> <i>Physics and Technology of Semiconductor Devices</i>		6 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport)</li> <li>2. Semiconductor diodes and transistors</li> <li>3. Semiconductor technology</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport.</li> <li>• Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors.</li> <li>• Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes and transistors</li> <li>• Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication.</li> <li>• Integrated acquisition of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid state physics, statistical physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Physics and Technology of Semiconductor Devices</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- Yu und Cardona: Fundamentals of Semiconductors (Springer)
- Sze: Physics of Semiconductor Devices (Wiley)
- Sze: Semiconductor Devices (Wiley)
- Madelung: Halbleiterphysik (Springer)
- Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)

**Part of the Module: [Physics and Technology of Semiconductor Devices \(Tutorial\)](#)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

see module description

**Examination**

**Physics and Technology of Semiconductor Devices**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Physics and Technology of Semiconductor Devices

<b>Module PHM-0049: Nanostructures / Nanophysics</b> <i>Nanostructures / Nanophysics</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. István Kézsmárki		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Semiconductor quantum wells, wires and dots, low dimensional electron systems</li> <li>2. Magnetotransport in low-dimensional systems, Quantum-Hall-Effect, Quantized conductance</li> <li>3. Optical properties of nanostructures and their application in modern optoelectronic devices, Nanophotonics</li> <li>4. Fabrication and detection techniques of nanostructures</li> <li>5. Ferroic properties of nanostructures (Ferroelectricity, Magnetism, Multiferroicity)</li> <li>6. Nano-bio-magnetism (magnetotactic bacteria, magnetoreception, malaria)</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students gain basic knowledge of the fundamental concepts in modern nanoscale science.</li> <li>• The students have detailed knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics</li> <li>• The students gain competence in selecting different fabrication and characterization approaches for specific nanostructures.</li> <li>• The students are able apply these concepts to tackle present problems in nanophysics.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Nanostructures / Nanophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- Yu und Cardona: Fundamentals of Semiconductors
- Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)
- Davies: The Physics of low-dimensional Semiconductors (Cambridge University Press)

**Examination**

**Nanostructures / Nanophysics**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Nanostructures / Nanophysics

<b>Module PHM-0203: Physics of Cells</b> <i>Physics of Cells</i>		6 ECTS/LP
Version 1.3.0 (since SoSe22) Person responsible for module: Dr. Christoph Westerhausen		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Physical principles in Biology</li> <li>Cell components and their material properties: cell membrane, organelles, cytoskeleton</li> <li>Thermodynamics of proteins and biological membranes</li> <li>Physical methods and techniques for studying cells</li> <li>Cell adhesion – interplay of specific, universal and elastic forces</li> <li>Tensile strength and elasticity of tissue - macromolecules of the extra cellular matrix</li> <li>Micro mechanics and properties of the cell as a biomaterial</li> <li>Cell adhesion</li> <li>Cell migration</li> <li>Cell actuation, cell-computer-communication, and cell stimulation</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>know basic physical properties of human cells, as building blocks of living organisms and their material properties.</li> <li>know the basic functionality of mechanical and optical methods to study living cells</li> <li>know physical descriptions of fundamental biological processes and properties of biomaterials.</li> <li>are able to express biophysical questions and define model systems to answer these questions.</li> </ul> The students improve the key competences: <ul style="list-style-type: none"> <li>self-dependent working with English specialist literature.</li> <li>processing of experimental data.</li> <li>interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Mechanics, Thermodynamics		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Physics of Cells</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English / German		
<b>Contact Hours:</b> 2		
<b>Learning Outcome:</b> see module description		

<p><b>Contents:</b> see module description</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Sackmann, Erich, and Rudolf Merkel. <i>Lehrbuch der Biophysik</i>. Wiley-VCH, 2010.</li> <li>• Heimburg, Thomas. <i>Thermal Biophysics of Membranes</i>. Wiley-VCH, 2007</li> <li>• Nelson, Philip. <i>Biological physics</i>. New York: WH Freeman, 2004.</li> <li>• Boal, D. <i>Mechanics of the Cell</i>. Cambridge University Press, 2012</li> <li>• Lecture notes</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Physics of Cells</b> (lecture)</p>
<p><b>Part of the Module: Physics of Cells (Tutorial)</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> English / alle Sprachen  <b>Contact Hours:</b> 2</p>
<p><b>Learning Outcome:</b> see module description</p>
<p><b>Contents:</b> see module description</p>
<p><b>Literature:</b> see module description</p>
<p><b>Assigned Courses:</b></p> <p><b>Physics of Cells (Tutorial)</b> (exercise course)</p>
<p><b>Examination</b></p> <p><b>Physics of Cells</b> oral exam / length of examination: 30 minutes, graded</p>

<b>Module MRM-0155: Resource and Waste Mineralogy</b> <i>Rohstoff- und Abfallmineralogie</i>		6 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Daniel Vollprecht		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Introduction: What is Mineralogy?</li> <li>2. General Mineralogy</li> <li>3. Special Mineralogy</li> <li>4. Economic Geology</li> <li>5. Mineral Processing</li> <li>6. Technical Mineralogy</li> <li>7. Archaeometry</li> <li>8. Waste Mineralogy</li> <li>9. Environmental Mineralogy</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• know the research subject and research methods of mineralogy</li> <li>• are able to determine the most important minerals by their diagnostic properties</li> <li>• understand the processes of formation of deposits</li> <li>• know mineral property and element raw materials</li> <li>• understand mineral reactions in technical processes of metallurgy and ceramics</li> <li>• understand the principles of hydraulic and alkali-activated binders</li> <li>• understand the inorganic-chemical reactions in thermal waste treatment plants</li> <li>• know mineral by-products and wastes</li> <li>• know the application of mineralogical methods in archaeology</li> <li>• are able to apply mineralogical methods to mineral resources and wastes</li> <li>• understand the interactions between natural and synthetic mineral phases and their environment</li> </ul>		
<b>Remarks:</b> Registration via Digicampus required		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> Comprehensive knowledge of chemistry		<b>Credit Requirements:</b> Participation in the exercises Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Rohstoff- und Abfallmineralogie</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		
<b>Learning Outcome:</b> see module description		



<b>Contents:</b> see module description
<b>Literature:</b> Bulakh & Wenk: Minerals. Their Constitution and Origin Baumann, Nikolskij & Wolf: Einführung in die Geologie und Erkundung von Lagerstätten Götze & Göbbels: Einführung in die Angewandte Mineralogie Amthauer & Pavicevic: Physikalisch-Chemische Methoden in den Geowissenschaften
<b>Examination</b> <b>Rohstoff- und Abfallmineralogie</b> portfolio exam, graded
<b>Parts of the Module</b>
<b>Part of the Module: Übung zu Rohstoff- und Abfallmineralogie</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English / German <b>Contact Hours:</b> 2
<b>Learning Outcome:</b> see module description
<b>Contents:</b> Determination exercises, lab experiments, field trips, industrial excursions

<b>Module PHM-0270: Computational Chemistry and Material Modeling</b> <i>Computerchemie/Materialmodellierung</i>		6 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: PD Georg Eickerling		
<b>Contents:</b> The lecture provides advanced insights into computational chemistry and modeling of molecular and solid-state materials: <ul style="list-style-type: none"> <li>• advanced introduction into the methods and concepts of quantum-chemical calculations</li> <li>• <i>mean-field</i> and <i>Density Functional Theory</i> methods</li> <li>• methods for describing electronic correlation</li> <li>• modeling chemical reactions of molecular compounds</li> <li>• from molecules to solids: modeling materials employing periodic boundary conditions</li> <li>• modeling dynamic and spectroscopic properties of molecules and solids (IR, Raman, NMR UV/VIS)</li> <li>• modeling materials under pressure</li> <li>• modeling surfaces</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• know advanced concepts for modeling molecular and solid state compounds</li> <li>• are able to evaluate the applicability of these concepts to a range of questions that might occur within the scope of materials chemistry and are thus able to evaluate the required and achievable accuracy of the selected computational method</li> <li>• are able to apply the obtained knowledge of the theoretical concepts within the scope of hands-on quantum chemical calculations and under guidance develop strategies for investigating theoretical aspects of materials chemistry</li> <li>• have the expertise to analyze, understand and evaluate the results obtained from different quantum chemical calculation methods and are competent to develop strategies for an advanced analysis of thus problems</li> </ul>		
<b>Workload:</b> Total: 180 h 45 h lecture (attendance) 15 h exercise course (attendance) 30 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h (self-study)		
<b>Conditions:</b> It is recommended to attend module PHM-0248 first.		<b>Credit Requirements:</b> passing the module examination
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Computational Chemistry and Material Modeling</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 3		

**Contents:**

see description of module

**Lehr-/Lernmethoden:**

blackboard and projector presentation

**Literature:**

- I. N. Levine *Quantum Chemistry*, 7th Ed., Pearson, Boston, US **2013**.
- A. Szabo, N. S. Ostlund *Modern Quantum Chemistry*, Dover, NY, US **1996**.
- E. G. Lewars *Computational Chemistry*, 3rd Ed., Springer, Cham, Switzerland, **2016**.
- D. C. Young *Computational Chemistry: A practical guide for applying techniques to real world problems*, Wiley, NY, US **2001**.
- R. A. van Santen, Ph. Sautet *Computational Methods in Catalysis and Materials Science*, Wiley, Weinheim, Deutschland, **2009**.
- J. B. Foresman, *Exploring Chemistry with Electronic Structure Methods*, 3rd Ed., Gaussian Inc., Wallingford, US, **2015**.

**Part of the Module: Tutorials for Computational Chemistry and Material Modeling****Mode of Instruction:** exercise course**Language:** German**Contact Hours:** 1**Lehr-/Lernmethoden:**

blackboard and projector presentation, practical exercises at the computer

**Examination****Computerchemie/Materialmodellierung**

written exam / length of examination: 90 minutes, graded

<b>Module PHM-0276: Modern Diffraction Techniques in Materials Science</b> <i>Moderne Diffraktionsmethoden in den Materialwissenschaften</i>		6 ECTS/LP
Version 1.1.0 (since SoSe22) Person responsible for module: PD Georg Eickerling		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• The independent atom model (IAM)</li> <li>• static and dynamic structure factors</li> <li>• limitations and failure of the IAM</li> <li>• the <math>\kappa</math>-formalism for the description of the atomic form factor</li> <li>• the multipolar expansion of the electron density: the Hansen-Coppens Model</li> <li>• Outlook: X-ray constrained wave functions</li> <li>• Applications: combined experimental and theoretical charge density studies</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• gain the basic competence required for the reconstruction of highly precise electron density distribution maps from X-ray diffraction data</li> <li>• know the basics of the quantum theory of atoms in molecules</li> <li>• are under guidance competent to analyze the topology of the electron density and are able to correlate the obtained results to the chemical properties of materials</li> </ul>		
<b>Workload:</b> Total: 180 h 90 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 45 h lecture (attendance) 15 h exercise course (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> passing the module examination
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Modern Diffraction Techniques in Materials Science</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 3		
<b>Lehr-/Lernmethoden:</b> blackboard and projector presentation		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• C. Giacovazzo et al., Fundamentals of Crystallography, Oxford Univ. Press, 2011.</li> <li>• P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.</li> <li>• P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.</li> </ul>		
<b>Assigned Courses:</b>		

**Moderne Diffraktionsmethoden in den Materialwissenschaften** (lecture)

**Part of the Module: Modern Diffraction Techniques in Materials Science**

**Mode of Instruction:** exercise course

**Language:** German

**Contact Hours:** 1

**Lehr-/Lernmethoden:**

blackboard and beamer presentation, hands-on tutorials at the computer

**Assigned Courses:**

**Übung zu Moderne Diffraktionsmethoden in den Materialwissenschaften** (exercise course)

**Examination**

**Moderne Diffraktionsmethoden in den Materialwissenschaften**

written exam / length of examination: 90 minutes, graded

<b>Module PHM-0301: Supramolecules and molecular design in materials science</b> <i>Supramoleküle und molekulares Design in den Materialwissenschaften</i>		6 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Dr. Hana Bunzen		
<b>Contents:</b> <ul style="list-style-type: none"> <li>An introduction and historical overview (supramolecular chemistry, self-assembly, supramolecular materials, molecular machines, etc.)</li> <li>Non-covalent interactions (e.g. H-bonds, electrostatic interactions, hydrophobic effect), thermodynamics</li> <li>Host-guest chemistry and typical hosts (e.g. calixarenes, resorcinarenes, crown ethers, cucurbiturils, cyclodextrins)</li> <li>Concepts of supramolecular synthesis (e.g. template, self-organization, self-sorting, cooperative binding)</li> <li>Methods for characterization of supramolecular compounds (e.g. NMR, UV/Vis titrations, mass spectrometry)</li> <li>Functional molecules (e.g. molecular switches, rotaxanes, sensors, molecular machines)</li> <li>Supramolecular materials (non-covalent polymers, gelators, liquid crystals)</li> <li>Supramolecular interactions in biological molecules (protein folding, ion channels, cell membranes)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>know the basic concepts of supramolecular chemistry and typical host molecules, and have a detailed understanding of non-covalent interactions between molecules,</li> <li>can apply the concepts of supramolecular synthesis to unknown compounds and find ways to prepare them,</li> <li>are familiar with methods for analyzing non-covalent interactions and for structural characterization of supramolecular compounds,</li> <li>know the importance of supramolecular chemistry for functional molecules, in materials science and in living systems,</li> <li>acquire scientific skills to search for scientific literature and to evaluate scientific content,</li> <li>are able to independently acquire further knowledge of the scientific topic using various forms of information</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in organic chemistry, basic knowledge in coordination chemistry		<b>Credit Requirements:</b> one written examination, 90 min.
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Supramolecules and molecular design in materials science</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3
<b>Contents:</b> see module description
<b>Literature:</b> J. Steed, J. Atwood: Supramolecular Chemistry (Wiley) W. Jones, C.N.R. Rao, Supramolecular Organization and Materials Design (Cambridge University Press)
<b>Part of the Module: Supramolecules and molecular design in materials science (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Contact Hours:</b> 1
<b>Examination</b> <b>Supramolecules and molecular design in materials science</b> written exam / length of examination: 90 minutes, graded <b>Examination Prerequisites:</b> Supramolecules and molecular design in materials science

<b>Module PHM-0361: Catalysis</b> <i>Catalysis</i>		6 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Wolfgang Scherer		
<b>Contents:</b> Introduction to catalysis (history and milestones) Basic principles of <i>homogeneous</i> and <i>heterogeneous</i> catalysis Homogeneous and heterogeneous <i>catalytic processes</i>  Examples: <ul style="list-style-type: none"> <li>• Activation and utilization of carbon dioxide in catalytic processes</li> <li>• Methane conversion to methanol, hydrogen and ammonia</li> <li>• Carbonylation of methanol</li> <li>• Carbon monoxide conversion</li> <li>• Nitrogen fixation</li> <li>• Polymerization of olefines</li> <li>• Hydrogenation and hydroformylation of olefins, Fischer-Tropsch synthesis, C1 chemistry</li> <li>• Metathesis</li> </ul>		
<b>Learning Outcomes / Competences:</b> By completing this course, the students <ul style="list-style-type: none"> <li>• gain the <i>knowledge</i> in fundamental concepts of homogeneous and heterogeneous catalysis to <i>understand</i> complex reaction mechanisms, the chemical bonding, structural chemistry and chemical properties of homogeneous and heterogeneous catalysts.</li> <li>• they gain <i>practical skills</i> to synthesize and characterize homogeneous and heterogeneous catalysts by means of spectroscopic techniques (UV-Vis, NMR, IR und Raman spectroscopy).</li> <li>• they gain the <i>intellectual skills</i> to design/optimize catalysts with regard to external control parameters (pressure, temperature, solvents) and intrinsic factors (steric request/electronic structure of the catalytically active sites).</li> <li>• they obtain the <i>transferrable skills</i> to extract relevant information from scientific literature.</li> </ul>		
<b>Remarks:</b> The module can be studied in the MSc programs "Materialchemie", "Materials Science" and "Materials Science and Engineering"		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> Basic knowledge in inorganic and organic chemistry		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Catalysis</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 3		



<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Lehr-/Lernmethoden:</b> projector presentation, blackboard
<b>Literature:</b> <ul style="list-style-type: none"><li>• D. Steinborn, <i>Grundlagen der metallorganischen Komplexkatalyse</i>, SpringerSpektrum, 3. Auflage, 2019.</li><li>• Hans-Jürgen Arpe, <i>Industrielle Organische Chemie</i>, Wiley-VCH, 6. Auflage, 2007.</li></ul>
<b>Assigned Courses:</b> <b>Catalysis</b> (lecture)
<b>Part of the Module: Übung zu Catalysis</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English / German <b>Contact Hours:</b> 1
<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Lehr-/Lernmethoden:</b> projector presentation, blackboard
<b>Literature:</b> See module part "Lecture"
<b>Assigned Courses:</b> <b>Übung zu Catalysis</b> (exercise course)
<b>Examination</b> <b>Catalysis</b> written exam / length of examination: 90 minutes, graded

<b>Module PHM-0218: Novel Methods in Solid State NMR Spectroscopy</b> <i>Novel Methods in Solid State NMR Spectroscopy</i>		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
<b>Contents:</b> The physical basis of nuclear magnetic resonance Pulsed NMR methods; Fourier Transform NMR Internal interactions Magic Angle Spinning Modern pulse sequences or how to obtain specific information about the structure and dynamics of solid materials Recent highlights of the application of modern solid state NMR in materials science		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Novel Methods in Solid State NMR Spectroscopy</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 3		
<b>Assigned Courses:</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> (lecture)		
<b>Part of the Module: Novel Methods in Solid State NMR Spectroscopy (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Contact Hours:</b> 1		
<b>Literature:</b> 1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008. 2. H. Günther, NMR spectroscopy, Wiley 2001. 3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004. 4. D. Canet: NMR - concepts and methods, Springer, 1994.		
<b>Assigned Courses:</b> <b>Novel Methods in Solid State NMR Spectroscopy (Tutorial)</b> (exercise course)		
<b>Examination</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> written exam / length of examination: 90 minutes, graded		

<b>Module PHM-0167: Oxidation and Corrosion</b> <i>Oxidation and Corrosion</i>	6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider	
<b>Contents:</b> Introduction Review of thermodynamics Chemical equilibria Electrochemistry Electrode kinetics High temperature oxidation Localized corrosion <ul style="list-style-type: none"> <li>• Shallow pit corrosion</li> <li>• Pitting corrosion</li> <li>• Crevice corrosion</li> <li>• Intercrystalline corrosion</li> <li>• Stress corrosion cracking</li> <li>• Fatigue corrosion</li> <li>• Erosion corrosion</li> <li>• Galvanic corrosion</li> </ul> Water and seawater corrosion Corrosion monitoring Corrosion properties of specific materials Specific corrosion problems in certain branches <ul style="list-style-type: none"> <li>• Oil and Gas industry</li> <li>• Automobile industry</li> <li>• Food industry</li> </ul> Corrosion protection <ul style="list-style-type: none"> <li>• Passive layers</li> <li>• Reaction layers (Diffusion layers ...)</li> <li>• Coatings (organic, inorganic)</li> <li>• Cathodic, anodic protection</li> <li>• Inhibitors</li> </ul>	
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the the fundamental basics, mechanics, types of corrosion processes and their electrochemical explanation</li> <li>• obtain the skill to understand typical electrochemical quantification of corrosion processes.</li> <li>• acquire the competence to assess corrosion phenomena from typical damage patterns</li> </ul>	
<b>Remarks:</b> Scheduled every second summer semester.	
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance)	

120 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: good knowledge in materials science, basic knowledge in physical chemistry		<b>Credit Requirements:</b> written exam (90 min)
<b>Frequency:</b> each summer semester alternating with PHM-0168	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Oxidation and Corrosion****Mode of Instruction:** lecture**Language:** English**Frequency:** each winter semester**Contact Hours:** 3**Literature:**

- Schütze: Corrosion and Environmental Degradation

**Assigned Courses:****Oxidation and Corrosion** (lecture)**Part of the Module: Oxidation and Corrosion (Tutorial)****Mode of Instruction:** exercise course**Language:** English**Frequency:** each winter semester**Contact Hours:** 1**Assigned Courses:****Oxidation and Corrosion (Tutorial)** (exercise course)**Examination****Oxidation and Corrosion**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Oxidation and Corrosion

<b>Module PHM-0264: Functional and Smart Macromolecular Materials</b>	6 ECTS/LP
Version 1.2.0 (since WS21/22) Person responsible for module: PD Dr. Klaus Ruhland	
<p><b>Contents:</b></p> <p><b><u>Electro-active polymeric materials</u></b></p> <ul style="list-style-type: none"> <li>• Intrinsically electric conducting polymers (ICPs)</li> <li>• Working principles of ICPs in selected applications</li> <li>• Red/Ox-responsive ICPs</li> <li>• Electrochromism</li> <li>• Electroactive Actuators</li> <li>• Non-electric-conducting electrically functional polymers</li> <li>• Ferroelectric polymers</li> <li>• Piezoelectric polymers</li> <li>• Dielectric elastomers</li> </ul> <p><b><u>Thermo-active polymeric materials</u></b></p> <ul style="list-style-type: none"> <li>• Difference between invertibility and reversibility</li> <li>• Pyro-electric effect vs electro-caloric effect</li> <li>• High-temperature-stabile polymers</li> <li>• Thermochromic polymers</li> </ul> <p><b><u>Mechano-active polymeric materials</u></b></p> <ul style="list-style-type: none"> <li>• Shape-Memory-polymers</li> <li>• Self-healing polymers</li> </ul> <p><b><u>Photo-active polymeric materials</u></b></p> <ul style="list-style-type: none"> <li>• Important chromophors and switching mechanisms</li> <li>• Photo-responsive polymerization initiators and catalysts</li> </ul> <p><b><u>Smart polymer gels</u></b></p> <ul style="list-style-type: none"> <li>• Thermo-responsive polymer gels (LCST/UCST)</li> <li>• Electrically charged polymer gels</li> <li>• pH-responsive polymer gels</li> </ul>	
<p><b>Learning Outcomes / Competences:</b></p> <p>The Students get to know which functional properties can be implemented into macromolecular materials by action of which external stimulus.</p> <p>They reach the ability to differentiate between different mechanisms to introduce smart behaviour into polymeric materials and to decide about dependences between different external stimuli.</p> <p>They will be competent to design smart functional multi-responsive macromolecular materials that serve specific application needs time- and space-dependent.</p> <p>Examples for applications of this type of material design will be discussed.</p>	
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>80 h studying of course content using provided materials (self-study)</p> <p>20 h studying of course content using literature (self-study)</p> <p>60 h lecture (attendance)</p> <p>20 h exercise course (attendance)</p>	
<b>Conditions:</b> none	<b>Credit Requirements:</b> passing the final examination

<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Functional and Smart Macromolecular Materials****Mode of Instruction:** lecture**Language:** German**Contact Hours:** 4**Contents:**

see description of the module

**Lehr-/Lernmethoden:**

see description of the module

**Literature:**

- Smart Polymers and their Applications; M. R. Aguilar, J. S. Roman (ISBN 978-0-85709-695-1)
- Functional Monomers and Polymers; K. Takemoto, R. M. Ottenbrite, M. Kamachi (ISBN 0-8247-9991-7)
- Biomedical Applications of Electroactive Polymer Actuators; F. Carpi, E. Smela (ISBN 978-0-470-77305-5)
- Electroactive Polymer Actuators as Artificial Muscles; Y. Bar-Cohen (ISBN0-8194-5297-1)
- Smart Polymers; I. Galaev, B. Mattiasson (ISBN 978-0-8493-9161-3)
- Semiconducting and Metallic Polymers; A. J. Heeger, N. S. Sariciftci, E. B. Namdas (ISBN 978-0-19-852864-7)
- Polymers and Light; W. Schnabel (ISBN978-3-527-31866-7)
- Shape Memory Polymers; J. Hu (ISBN 978-1-90903-050-3)
- Shape Memory Materials; D. I. Arun, P. Chakravarthy, K. R. Arockia, B. Santhosh (ISBN 978-0-367-57169-6)
- Polymer Materials with Smart Properties; M. Bercea (ISBN 978-1-62808-876-2)
- Self-healing Materials; K. Ghosh (ISBN 978-3-527-31829-2)
- Self-Healing Polymers; W. H. Binder (ISBN 978-3-527-33439-1)
- High Performance Polymers; J. K. Fink (ISBN 978-0-8155-1580-7)
- Functional Coatings; S. K. Ghosh (ISBN 978-3-527-31296-2)
- Handbook of Stimuli-Responsive Materials; M. W. Urban (ISBN 978-3-527-32700-3)
- Renewable Resources for Functional Polymers and Biomaterials; P. A. Williams (ISBN 978-1-84973-245-1)
- Thermochromic and Thermotropic Materials; A. Seeboth, D. Löttsch (ISBN 978-981-4411-02-8)
- Thermochromic Phenomena in Polymers; A. Seeboth, D. Löttsch (ISBN 978-1-84735-112-8)
- Shape-Memory Polymers for Aerospace Applications; G. P. Tandon, A. J. W. McClung, J. W. Baur (ISBN 978-1-60595-118-8)
- Polymer Mechanochemistry; R. Boulatov (ISBN 978-3-319-22824-2)

**Assigned Courses:****Functional and Smart Macromolecular Materials** (lecture)**Examination****Functional and Smart Macromolecular Materials**

written exam / length of examination: 90 minutes, graded

<b>Module MRM-0153: CMC product development using ICME (Integrated Computational Materials Engineering)</b> <i>CMC-Produktentwicklung mittels ICME (Integrated Computational Materials Engineering)</i>		6 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr.-Ing. Dietmar Koch		
<b>Contents:</b> The development of ceramic fiber composite components is an iterative product development process due to the component-specific material properties. These iterations serve to assess feasibility or material characterization and are often associated with time-, cost-, and resource-intensive testing programs, feature prototypes, or demonstrator components. Therefore, this approach is heuristic (trial and error). In contrast, CMC (Ceramic Matrix Composite) product development through ICME (Integrated Computational Materials Engineering) aims to partially shift the development process into the virtual space using ICME tools, thereby minimizing real sample and component testing through the use of digital models. The ICME approach originally developed for metallic materials can be applied particularly to fiber-reinforced composites due to their pronounced dependence on material properties on the manufacturing process and component geometry.		
<b>Learning Outcomes / Competences:</b> In the lecture on CMC (Ceramic Matrix Composite) product development using ICME (Integrated Computational Materials Engineering), students are provided with an overview of the current state of technology, the currently available ICME tools in the field of fiber-reinforced composites, and their application through case studies.		
<b>Conditions:</b> Keine		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Übung zu CMC-Produktentwicklung mittels ICME (Integrated Computational Materials Engineering)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Contact Hours:</b> 1		
<b>Assigned Courses:</b> CMC-Produktentwicklung mittels ICME (Integrated Computational Materials Engineering) (lecture)		
<b>Parts of the Module</b>		
<b>Part of the Module: CMC-Produktentwicklung mittels ICME (Integrated Computational Materials Engineering)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 3		
<b>Lehr-/Lernmethoden:</b> Die Vorlesung findet im seminaristischen Stil statt und wird mit Fallstudien ergänzt. Die Übungen bestehen aus Übungsaufgaben zum aktuellen Vorlesungsinhalt. Zum Lösen der Aufgaben werden neben den Vorlesungsunterlagen und Musterlösungen auch eigens hierfür erstellte Kurzvideos bereitgestellt. Fragen zu den Aufgaben werden gemeinsam in der Vorlesung besprochen und geklärt.		
<b>Assigned Courses:</b>		

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**CMC-Produktentwicklung mittels ICME (Integrated Computational Materials Engineering) (lecture)**

**Examination**

**CMC-Produktentwicklung mittels ICME (Integrated Computational Materials Engineering)**

written exam / length of examination: 60 minutes, graded



<b>Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties</b> <i>Fiber Reinforced Composites: Processing and Materials Properties</i>		6 ECTS/LP
Version 1.2.0 (since SoSe15) Person responsible for module: Dr. Judith Moosburger-Will		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Production of fibers (e.g. glass, carbon, or ceramic fibers)</li> <li>• Physical and chemical properties of fibers and their precursor materials</li> <li>• Physical and chemical properties of commonly used polymeric and ceramic matrix materials</li> <li>• Semi-finished products</li> <li>• Composite production technologies</li> <li>• Application of fiber reinforced materials</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the physical and chemical properties of fibers, matrices, and fiber-reinforced materials.</li> <li>• know the basics of production technologies of fibers, polymeric, ceramic matrices, and fiber-reinforced materials.</li> <li>• know the application areas of composite materials.</li> <li>• have the competence to explain material properties of fibers, matrices, and composites.</li> <li>• have the competence to choose the right materials according to application relevant conditions.</li> <li>• are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge in materials science, basic lectures in organic chemistry		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Literature:**

- Morgan: Carbon fibers and their composites
- Ehrenstein: Polymeric materials
- Krenkel: Ceramic Matrix Composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

**Assigned Courses:**

**Fiber Reinforced Composites: Processing and Materials Properties** (lecture)

**Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Literature:**

see lecture

**Assigned Courses:**

**Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)** (exercise course)

**Examination**

**Fiber Reinforced Composites: Processing and Materials Properties**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Fiber Reinforced Composites: Processing and Materials Properties

<b>Module PHM-0122: Non-Destructive Testing</b> <i>Non-Destructive Testing</i>		6 ECTS/LP
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Markus Sause		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to nondestructive testing methods</li> <li>• Visual inspection</li> <li>• Ultrasonic testing</li> <li>• Guided wave testing</li> <li>• Acoustic emission analysis</li> <li>• Thermography</li> <li>• Radiography</li> <li>• Eddy current testing</li> <li>• Specialized nondestructive methods</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• acquire knowledge in the field of nondestructive evaluation of materials,</li> <li>• are introduced to important concepts in nondestructive measurement techniques,</li> <li>• are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Basic knowledge on materials science, in particular composite materials		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Non-Destructive Testing</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- Raj: Practical Non-destructive Testing
- Shull: Nondestructive Evaluation - Theory and Applications
- Krautkrämer: Ultrasonic testing of materials
- Grosse: Acoustic Emission Testing
- Rose: Ultrasonic waves in solid media
- Maldague: Nondestructive Evaluation of Materials by Infrared Thermography
- Herman: Fundamentals of Computerized Tomography

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

**Assigned Courses:**

**Non-Destructive Testing** (lecture)

**Part of the Module: Non-Destructive Testing (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Assigned Courses:**

**Non-Destructive Testing (Tutorial)** (exercise course)

**Examination**

**Non-Destructive Testing**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Non-Destructive Testing

<b>Module PHM-0168: Modern Metallic Materials</b> <i>Modern Metallic Materials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Introduction Review of physical metallurgy Steels: <ul style="list-style-type: none"> <li>• principles</li> <li>• common alloying elements</li> <li>• martensitic transformations</li> <li>• dual phase steels</li> <li>• TRIP and TWIP steels</li> <li>• maraging steel</li> <li>• electrical steel</li> <li>• production and processing</li> </ul> Aluminium alloys: <ul style="list-style-type: none"> <li>• 2xxx</li> <li>• 6xxx</li> <li>• 7xxx</li> <li>• Processing – creep forming, hydroforming, spinforming</li> </ul> Titanium alloys Magnesium alloys Superalloys Intermetallics, high entropy alloys		
<b>Learning Outcomes / Competences:</b> Students <ul style="list-style-type: none"> <li>• learn about relevant classes of actual metallic alloys and their properties</li> <li>• acquire the skill to derive alloy properties from physical metallurgy principles and concepts</li> <li>• have the competence to choose and to explain appropriate metallic materials for special applications</li> </ul>		
<b>Remarks:</b> Scheduled every second summer semester.		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: Knowledge of physical metallurgy and physical chemistry		
<b>Frequency:</b> each summer semester alternating with PHM-0167	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

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**Parts of the Module**

**Part of the Module: Modern Metallic Materials**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 4

**Literature:**

Cahn-Haasen-Kramer: Materials Science and Technology

Original literature

**Examination**

**Modern Metallic Materials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Modern Metallic Materials

<b>Module PHM-0196: Surfaces and Interfaces II: Joining processes</b> <i>Surfaces and Interfaces II: Joining processes</i>		6 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Dr. Judith Moosburger-Will		
<b>Learning Outcomes / Competences:</b> The students - know the application areas of composite materials - know the basics of cohesion and adhesion - know the basics of joining techniques - are introduced to physical and chemical properties metal-metal, metal-polymer and polymer-polymer interfaces - Are able to independently acquire further knowledge of the scientific topic using various forms of information.		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> Basic knowledge on materials science, lecture "Surfaces and Interfaces I" Module Surfaces and Interfaces (PHM-0117) - recommended		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> any	

<b>Parts of the Module</b>
<b>Part of the Module: Surfaces and Interfaces II: Joining processes</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Siegfried Horn <b>Language:</b> German <b>Contact Hours:</b> 3
<b>Contents:</b> The following topics are treated: - Introduction to adhesion - Role of surface and interface properties - Introduction to interactions at surfaces and interfaces - Adhesion theories - Surface and interface energy - Surface treatment techniques - Joining techniques - Physical and chemical properties of joints - Applications
<b>Lehr-/Lernmethoden:</b> Lecture: Beamer presentation and Blackboard Exercise: Exercises on recent topics, specialization of lecture contents
<b>Literature:</b> Literature, including actual scientific papers and reviews, will be announced at the beginning of the lecture.

**Examination**

**Surfaces and Interfaces II: Joining processes**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Surfaces and Interfaces II: Joining processes

**Parts of the Module**

**Part of the Module: Übung zu Surfaces and Interfaces II: Joining processes**

**Mode of Instruction:** exercise course

**Language:** German

**Contact Hours:** 1



<b>Module MRM-0136: Mechanical Characterization of Materials</b> <i>Mechanical Characterization of Materials</i>		6 ECTS/LP
Version 1.1.0 (since SoSe21) Person responsible for module: Prof. Dr. Markus Sause		
<b>Contents:</b> The following topics are presented: <ul style="list-style-type: none"> <li>• Introduction to material characterization</li> <li>• Linear material behaviour</li> <li>• Non-linear material behaviour</li> <li>• Material failure</li> <li>• Measurement technologies</li> <li>• Tensile testing</li> <li>• Compression testing</li> <li>• Shear testing</li> <li>• Other static testing concepts</li> <li>• Fracture mechanics</li> <li>• Assembly testing</li> <li>• Surface mechanics</li> <li>• Creep testing</li> <li>• Fatigue testing</li> <li>• High-Velocity testing</li> <li>• Component testing</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• Acquire knowledge in the field of materials testing and evaluation of materials.</li> <li>• Are introduced to important concepts in measurement techniques, and material models.</li> <li>• Are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> None		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Mechanical Characterization of Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Literature:**

- Issler, L., & Häfele, H. R. P. (2003). Festigkeitslehre — Grundlagen. Springer Berlin Heidelberg. <https://doi.org/10.1007/978-3-540-73485-7>
- Dowling, N. E. (2019). Mechanical Behavior of Materials (4th ed.). Pearson.
- Gross, D., & Seelig, T. (2011). Fracture Mechanics. Springer Berlin Heidelberg. <https://doi.org/10.1007/978-3-642-19240-1>
- J. Schijve. (2008). Fatigue of Structures and Materials (2nd Edition). Springer Science & Business Media.
- Sadd, M. H. (2018). Continuum Mechanics Modeling of Material Behavior. In Continuum Mechanics Modeling of Material Behavior. Elsevier. <https://doi.org/10.1016/C2016-0-01495-X>

**Examination**

**Mechanical Characterization of Materials**

written exam, written exam / length of examination: 90 minutes, graded

**Parts of the Module**

**Part of the Module: Mechanical Characterization of Materials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

<b>Module MRM-0112: Finite element modeling of multiphysics phenomena</b> <i>Finite-Elemente-Modellierung von Multiphysik-Phänomenen</i>		6 ECTS/LP
Version 2.9.0 (since WS19/20) Person responsible for module: Prof. Dr. Markus Sause Dozenten: Prof. Dr. Sause / Prof. Dr Peter		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• get to know existing numerical methods for modeling and simulation of physical processes and systems</li> <li>• Learn the use and application of numerical methods for realistic problems</li> <li>• Are able to apply basic functional principles of a FEM program by using "COMSOL Multiphysics".</li> </ul>		
<b>Remarks:</b> This module is offered by faculty from MRM and Mathematics. It is intended for physics, MSE and WING students, who want to get an insight into a modern FEM program as it is used in academic and industrial applications.		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> Recommended: MTH-6110 - Numerische Verfahren für Materialwissenschaftler, Physiker und Wirtschaftsingenieure		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Finite-Elemente-Modellierung von Multiphysik-Phänomenen</b>		
<b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Malte Peter, Prof. Dr. Markus Sause <b>Language:</b> German <b>Contact Hours:</b> 2		
<b>Contents:</b> The following content will be presented: <ul style="list-style-type: none"> <li>• Modeling and simulation of physical processes and systems.</li> <li>• Basic concepts of FEM programs</li> <li>• Generation of meshes</li> <li>• Optimization strategies</li> <li>• Selection of solver algorithms</li> <li>• Example applications from electrodynamics</li> <li>• Example applications from thermodynamics</li> <li>• Example applications from continuum mechanics</li> <li>• Example applications from fluid dynamics</li> <li>• Coupling of differential equations for the solution of multiphysics phenomena</li> </ul>		
<b>Lehr-/Lernmethoden:</b> Slide presentation, classroom discussion		

**Literature:**

- Grossmann, C., Roos, H.-G., & Stynes, M. (2007). Numerical Treatment of Partial Differential Equations. Springer Berlin Heidelberg. <https://doi.org/10.1007/978-3-540-71584-9>
- Eck, C., Garcke, H., & Knabner, P. (2017). Mathematische Modellierung. Springer Berlin Heidelberg. <https://doi.org/10.1007/978-3-662-54335-1>
- Temam, R., & Miranville, A. (2005). Mathematical Modeling in Continuum Mechanics. Cambridge: Cambridge University Press.

**Examination**

**Finite-Elemente-Modellierung von Multiphysik-Phänomenen**

written/oral exam / length of examination: 60 minutes, graded

**Parts of the Module**

**Part of the Module: Übung zu Finite-Elemente-Modellierung von Multiphysik-Phänomenen**

**Mode of Instruction:** exercise course

**Language:** German

**Contact Hours:** 2

**Lehr-/Lernmethoden:**

Independent reflection of topics to deepen the lecture content

<b>Module MRM-0126: Ceramic Matrix Composites</b> <i>Keramische Faserverbundwerkstoffe</i>		6 ECTS/LP
Version 3.0.0 (since WS21/22) Person responsible for module: Prof. Dr.-Ing. Dietmar Koch		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction in ceramic matrix composites</li> <li>• Basics of processing of technical ceramics</li> <li>• Processing chain of ceramic matrix composites (CMC) from raw materials to product</li> <li>• Processing and properties of ceramic fibers</li> <li>• Principal mechanisms of reinforcement in CMC</li> <li>• Properties of CMC</li> <li>• Application of CMC</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic concepts of mechanical behavior of ceramic matrix composites</li> <li>• The students have the competence to explain processing of ceramic fibers and ceramic matrix composites and describe their specific properties</li> <li>• The students know the Weibull statistics which describe the fiber strength distribution</li> <li>• The students know how to describe mechanical interactions between fiber and matrix</li> <li>• The students get the knowledge of application of ceramic matrix composites and are able to choose the according material for specific application.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content</li> </ul>		
<b>Workload:</b> Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge of materials		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Keramische Faserverbundwerkstoffe</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see description of module		
<b>Contents:</b> see description of module		

**Literature:**

- N.P. Bansal, J. Lamon, Ceramic Matrix Composites: Materials, Modeling and Technology. John Wiley & Sons, Inc., 2015.
- W. Krenkel, Ceramic Matrix Composites. Wiley-VCH Verlag GmbH & Co. KGaA, 2008.
- K. K. Chawla, Composite Materials 3rd ed., Springer, 2012
- T. Ohji, M. Singh, Engineered Ceramics: Current Status and Future Prospects, ISBN: 978-1-119-10042-3, 2015

**Assigned Courses:**

**Keramische Faserverbundwerkstoffe** (lecture)

**Examination**

**Keramische Faserverbundwerkstoffe**

written exam, written exam / length of examination: 60 minutes, graded

**Parts of the Module**

**Part of the Module: Übung Keramische Faserverbundwerkstoffe**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Learning Outcome:**

see description of module

**Contents:**

see description of module

**Literature:**

see description of module

**Assigned Courses:**

**Keramische Faserverbundwerkstoffe** (lecture)

<b>Module MRM-0089: Recycling of composites</b> <i>Recycling von Verbundwerkstoffen (Composites)</i>		6 ECTS/LP
Version 3.0.0 (since SoSe23) Person responsible for module: Dr. Kunzmann		
<b>Learning Outcomes / Competences:</b> Die Studierenden lernen <ul style="list-style-type: none"> <li>• basierend auf den möglichen Grundprinzipien der Stofftrennung die Kriterien für die richtige Verfahrenswahl im Bereich Recycling von Faserverbundwerkstoffen (Composites) kennen und üben deren Anwendung in Beispielaufgaben</li> <li>• die wichtigsten Verfahren zur Stofftrennung und –aufbereitung kennen und analysieren deren technische Ausführungsformen und deren Auslegung an Beispielen</li> <li>• die Beurteilungsmaßstäbe für die unterschiedlichen Prozessschritte bezüglich technischer, qualitativer und wirtschaftlicher Kriterien auf die Prozessschritte des Recyclings anzuwenden</li> <li>• die wichtigsten chemischen, physikalischen und technischen Schritte der Stofftrennung auf das Recycling von Composites anzuwenden</li> </ul>		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 3	<b>Repeat Exams Permitted:</b> any	
<b>Parts of the Module</b>		
<b>Part of the Module: Recycling von Verbundwerkstoffen (Composites)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 2		

**Contents:**

- Prinzipien der Stofftrennung beim Recycling von Rohstoffen
  - Chemische Trennung
  - Physikalische Trennung
  - Mechanische Trennung
  - Sonderformen der Separierung
- Stoffgruppen des Verbundwerkstoff Recyclings
  - End of Life (EOL) Bauteile
  - Verharzte Abfälle
  - Unverharzte Abfälle
- Prozessabläufe und –verfahren der Stoffseparierung
  - Trennung der Kunststofffraktionen (Harze, Thermoplaste) und der textilen Fraktionen
    - 1) Pyrolyse
    - 2) Solvolyse
    - 3) Chemische Verfahren
  - Kunststoffrecycling
  - Textilrecycling
    - 1) Vorbereitung
    - 2) Öffnen
    - 3) Mischen
- Herstellung textiler Halbzeuge
  - Vliesbilden
  - Garnbilden
  - Flächenerzeugung aus Geweben, Gewirken, Geflechten, Gelegen
  - Direktformen
- Weiterverarbeitung zu Composites
- Weiterverarbeitung zu anderen Recyclingprodukten
- Auslegung und Wirtschaftlichkeit
- Ökologische Bilanzierung, LCA

**Examination**

**Recycling von Verbundwerkstoffen (Composites)**

written exam / length of examination: 90 minutes, graded

**Parts of the Module**

**Part of the Module: Übung zu Recycling von Verbundwerkstoffen (Composites)**

**Mode of Instruction:** exercise course

**Language:** German

**Contact Hours:** 1

**Contents:**

- Auslegung und Berechnung der einzelnen Verfahrensschritte des Composite Recyclings
- Erarbeitung von Kriterienkatalogen für die Auswahl der Prozessschritte
- Praktische Übungen an Maschinen des Textil Recyclings im Labor des Instituts für Textiltechnik Augsburg
- Realisierung von Demonstrator Halbzeugen aus eigener Berechnung und Versuchen an Pilotmaschinen
- Exkursionen zu ausgewählten Betrieben der Recyclingindustrie



<b>Module MRM-0126: Ceramic Matrix Composites</b> <i>Keramische Faserverbundwerkstoffe</i>		6 ECTS/LP
Version 3.0.0 (since WS21/22) Person responsible for module: Prof. Dr.-Ing. Dietmar Koch		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction in ceramic matrix composites</li> <li>• Basics of processing of technical ceramics</li> <li>• Processing chain of ceramic matrix composites (CMC) from raw materials to product</li> <li>• Processing and properties of ceramic fibers</li> <li>• Principal mechanisms of reinforcement in CMC</li> <li>• Properties of CMC</li> <li>• Application of CMC</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic concepts of mechanical behavior of ceramic matrix composites</li> <li>• The students have the competence to explain processing of ceramic fibers and ceramic matrix composites and describe their specific properties</li> <li>• The students know the Weibull statistics which describe the fiber strength distribution</li> <li>• The students know how to describe mechanical interactions between fiber and matrix</li> <li>• The students get the knowledge of application of ceramic matrix composites and are able to choose the according material for specific application.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content</li> </ul>		
<b>Workload:</b> Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge of materials		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Keramische Faserverbundwerkstoffe</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see description of module		
<b>Contents:</b> see description of module		

<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• N.P. Bansal, J. Lamon, Ceramic Matrix Composites: Materials, Modeling and Technology. John Wiley &amp; Sons, Inc., 2015.</li> <li>• W. Krenkel, Ceramic Matrix Composites. Wiley-VCH Verlag GmbH &amp; Co. KGaA, 2008.</li> <li>• K. K. Chawla, Composite Materials 3rd ed., Springer, 2012</li> <li>• T. Ohji, M. Singh, Engineered Ceramics: Current Status and Future Prospects, ISBN: 978-1-119-10042-3, 2015</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Keramische Faserverbundwerkstoffe</b> (lecture)</p>
<p><b>Examination</b></p> <p><b>Keramische Faserverbundwerkstoffe</b></p> <p>written exam, written exam / length of examination: 60 minutes, graded</p>
<p><b>Parts of the Module</b></p>
<p><b>Part of the Module: Übung Keramische Faserverbundwerkstoffe</b></p> <p><b>Mode of Instruction:</b> exercise course</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 1</p>
<p><b>Learning Outcome:</b></p> <p>see description of module</p>
<p><b>Contents:</b></p> <p>see description of module</p>
<p><b>Literature:</b></p> <p>see description of module</p>
<p><b>Assigned Courses:</b></p> <p><b>Keramische Faserverbundwerkstoffe</b> (lecture)</p>

<b>Module PHM-0252: Optical Excitations in Materials</b> <i>Optical Excitations in Materials</i>		6 ECTS/LP
Version 1.9.0 (since SoSe20) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
<b>Contents:</b> <ol style="list-style-type: none"> <li>Classical Light-Matter Interaction in Solids: <ul style="list-style-type: none"> <li>Introduction: Typical Optical Response of Metals and Semiconductors</li> <li>Classical electromagnetic wave propagation in linear optical media (Maxwell Equations, refractive index, reflection, transmission, absorption)</li> <li>Anisotropic media, birefringence, longitudinal solutions</li> <li>Classical Drude-Lorentz oscillator model</li> <li>Spectroscopic techniques: Fourier-Transform-Spectroscopy, Time-domain Spectroscopy, Ellipsometry</li> </ul> </li> <li>Quantum Aspects of Light-Matter interaction <ul style="list-style-type: none"> <li>qm approach to absorption and emission: Lorentzian lineshape, Fermi's Golden Rule</li> <li>Electric-dipole and magnetic-dipole approximation</li> <li>Rabi-oscillations and the need for quantum optical approaches</li> <li>A glimpse of non-linear optics</li> </ul> </li> <li>Excitations in different material classes <ul style="list-style-type: none"> <li>Optical properties of semiconductors/insulators, molecular materials, metals</li> <li>Absorption and Luminescence, excitons, luminescence centers</li> <li>Optoelectronics, detectors, light emitting devices</li> <li>Quantum confined structures: tuning of absorption and emission</li> </ul> </li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>The students gain basic knowledge of the fundamental concepts of light-matter interaction in solids.</li> <li>The students have detailed knowledge of classical models of light-propagation and absorption and get the competence to choose adequate spectroscopic techniques for measuring the optical properties of different material classes.</li> <li>The students have a basic understanding of quantum aspects of optical processes in different materials.</li> <li>The students are able to apply these concepts to understand and analyse optical properties of different materials.</li> <li>The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic knowledge of classical electrodynamics, atomic and solid state physics.		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module**

**Part of the Module: Optical Excitations in Materials**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 4

**ECTS Credits:** 6.0

**Literature:**

1. Mark Fox, Optical Properties of Solids, Oxford Master Series
2. Mark Fox, Quantum Optics: An Introduction, Oxford Master Series
3. David B. Tanner, Optical Effects in Solids, Cambridge University Press
4. Y. Toyozawa, Optical Processes in Solids, Cambridge University Press

**Assigned Courses:**

**Optical Excitations in Materials** (lecture)

**Examination**

**Optical Excitations in Materials**

written exam / length of examination: 90 minutes, graded

<b>Module PHM-0253: Dielectric Materials</b> <i>Dielectric Materials</i>		6 ECTS/LP
Version 2.0.0 (since SoSe23) Person responsible for module: PD Dr. Peter Lunkenheimer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Experimental techniques: quantities, broadband dielectric spectroscopy, nonlinear and polarization measurements</li> <li>• Dynamic processes in dielectric materials: relaxation processes, phenomenological models</li> <li>• Dielectric properties of disordered matter: liquids, glasses, plastic crystals</li> <li>• Charge transport: hopping conductivity, universal dielectric response</li> <li>• Ionic conductivity: conductivity mechanism, dielectric properties, advanced electrolytes for energy-storage devices</li> <li>• Maxwell-Wagner relaxations: equivalent-circuits, applications (supercapacitors), colossal-dielectric-constant materials</li> <li>• Electroceramics: Materials, Properties (relaxor ferroelectric, ferroelectric, antiferroelectric and multiferroic), Applications</li> </ul>		
<b>Learning Outcomes / Competences:</b> Students know the fundamentals of electromagnetic wave propagation and have a sound background for a broad spectrum of dielectric phenomena. They are able to analyze materials requirements and to interpret dielectric spectra in a broad frequency range. They have the competence to select materials for different kinds of applications and to critically assess experimental results on dielectric properties.		
<b>Remarks:</b> <b>Elective compulsory module</b>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic knowledge of solid state physics		<b>Credit Requirements:</b> Pass of module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Dielectric Materials</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> PD Dr. Peter Lunkenheimer <b>Language:</b> English / alle Sprachen		

**Literature:**

- F. Kremer and A. Schönhal (eds.), Broadband Dielectric Spectroscopy (Springer, Berlin, 2002).
- F. Kremer and A. Loidl (eds.), The scaling of relaxation processes (Springer, Cham, 2018).
- A.K. Jonscher, Dielectric Relaxations in Solids (Chelsea Dielectrics Press, London, 1983).
- C.J.F. Böttcher and P. Bordewijk, Theory of electric polarisation Vol II (Elsevier, Amsterdam, 1973).
- S.R. Elliott, Physics of Amorphous Materials (Longman, London, 1990)
- A.J. Moulson, J.M. Herbert, Electroceramics: Materials, Properties, Applications (Wiley, 2003)
- R. Waser, U. Böttger, S. Tiedke, Polar Oxides: Properties, Characterization, and Imaging (Wiley, 2005)

**Examination**

**Dielectric Materials Dielectric Materials**

presentation / length of examination: 45 minutes, graded

**Examination Prerequisites:**

Dielectric Materials

<b>Module PHM-0166: Carbon-based functional Materials (Carboterials)</b> <i>Carbon-based functional Materials (Carboterials)</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Introduction to carbon allotropes and porous carbon materials [4]</li> <li>2. Physical properties of fullerenes, carbon nanotubes and graphene [4]</li> <li>3. Solid state NMR spectroscopy of carbon materials [4]</li> <li>4. Metal carbides [4]</li> <li>5. Carbon thin films and coatings [4]</li> <li>6. Manufacturing and processing technology of carbon fibres [4]</li> <li>7. Carbon-fibre reinforced polymer composites [4]</li> <li>8. Carbon-fibre reinforced aluminium (Metal Matrix Composites, MMC) [4]</li> <li>9. Energy storage in carbon materials [4]</li> <li>10. Carbon-based materials for opto-electronics [4]</li> <li>11. Quantum transport phenomena relating to carbon materials [4]</li> <li>12. a) Manipulating heat flow with carbon-based electronic analogs: phononics in place of electronics [2]</li> <li>12. b) Carbon-based spintronics [2]</li> <li>13. Fabrication and processing of carbon-based nanostructures [4]</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basics of the chemistry and physics of carbon materials and their applications,</li> <li>• acquire knowledge about the structural characterization, physical properties and engineering of functional materials and carbon based devices,</li> <li>• learn to work with specialist literature in english.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

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**Parts of the Module**

**Part of the Module: Carbon-based functional Materials (Carboterials)**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 4

**Literature:**

will be announced by the lecturers

**Examination**

**Carbon-based functional Materials (Carboterials)**

written exam / length of examination: 120 minutes, graded

**Examination Prerequisites:**

Carbon-based functional Materials (Carboterials)



<b>Module PHM-0174: Theoretical Concepts and Simulation</b> <i>Theoretical Concepts and Simulation</i>		6 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Liviu Chioncel		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Introduction: operating systems, programming languages, data visualization tools</li> <li>2. Basic numerical methods: interpolation, integration</li> <li>3. Ordinary and Partial Differential Equations (e.g., diffusion equation, Schrödinger equation)</li> <li>4. Concepts in atomistic materials modelling</li> <li>5. Simulation of material's properties (molecular spectroscopy, magnetism)</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the principal concepts of the numerical methods relevant in material science,</li> <li>• are able to solve simple problems numerically. They are able to write the codes and to present the results,</li> <li>• are able to choose the adequate levels of description and approximations for a given problem and apply the corresponding methods,</li> <li>• have the expertise to judge the quality and validity of the numerical results,</li> <li>• Integrated acquirement of soft skills: independent handling of hard- and software while using English documentations, ability to investigate abstract circumstances with the help of a computer and to present the results in written and oral form, capacity for teamwork.</li> </ul>		
<b>Remarks:</b> Links to exemplary software related to the course: <ul style="list-style-type: none"> <li>• <a href="http://www.bloodshed.net/">http://www.bloodshed.net/</a></li> <li>• <a href="http://www.cplusplus.com/doc/tutorial/">http://www.cplusplus.com/doc/tutorial/</a></li> <li>• <a href="http://www.cygwin.com/">http://www.cygwin.com/</a></li> <li>• <a href="http://avogadro.cc/">http://avogadro.cc/</a></li> <li>• <a href="http://orcaforum.kofo.mpg.de/app.php/portal">http://orcaforum.kofo.mpg.de/app.php/portal</a></li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: basic knowledge of quantum mechanics, thermodynamics, and numerical methods as well as of a programming language		<b>Credit Requirements:</b> project work in small groups, including a written summary of the results (ca. 10-20 pages) as well as an oral presentation
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Theoretical Concepts and Simulation</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 3
<b>Literature:</b> <ul style="list-style-type: none"><li>• Tao Pang, An Introduction to Computational Physics (Cambridge University Press)</li><li>• J. M. Thijssen, Computational Physics (Cambridge University Press)</li><li>• Koonin, Meredith, Computational Physics (Addison-Weseley)</li><li>• D. C. Rapaport, The Art of Molecular Dynamics Simulation, (Cambridge University Press)</li><li>• W. H. Press et al, Numerical Recipes (Cambridge University Press)</li></ul>
<b>Assigned Courses:</b> <b>Theoretical Concepts and Simulation</b> (lecture)
<b>Part of the Module: Theoretical Concepts and Simulation (Project)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Contact Hours:</b> 1
<b>Assigned Courses:</b> <b>Theoretical Concepts and Simulation (Project)</b> (exercise course)
<b>Examination</b> <b>Theoretical Concepts and Simulation</b> seminar / length of examination: 30 minutes, graded <b>Examination Prerequisites:</b> Theoretical Concepts and Simulation

<b>Module PHM-0058: Organic Semiconductors</b> <i>Organic Semiconductors</i>		6 ECTS/LP
Version 1.6.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Brütting		
<b>Contents:</b> Basic concepts and applications of organic semiconductors Introduction <ul style="list-style-type: none"> <li>• Materials and preparation</li> <li>• Structural properties</li> <li>• Electronic structure</li> <li>• Optical and electrical properties</li> </ul> Devices and Applications <ul style="list-style-type: none"> <li>• Organic metals</li> <li>• Light-emitting diodes</li> <li>• Solar cells</li> <li>• Field-effect transistors</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic structural and electronic properties of organic semiconductors as well as the essential function of organic semiconductor devices,</li> <li>• have acquired skills for the classification of the materials taking into account their specific features in the functioning of components,</li> <li>• and have the competence to comprehend and attend to current problems in the field of organic electronics.</li> <li>• Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 40 h studying of course content through exercises / case studies (self-study) 40 h studying of course content using provided materials (self-study) 40 h studying of course content using literature (self-study)		
<b>Conditions:</b> It is strongly recommended to complete the module solid-state physics first. In addition, knowledge of molecular physics is desired.		
<b>Frequency:</b> Sommersemester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 5	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Organic Semiconductors</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Wolfgang Brütting <b>Language:</b> English <b>Contact Hours:</b> 3		

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)
- W. Brütting: Physics of Organic Semiconductors (Wiley-VCH)
- A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)
- S.R. Forrest: Organic Electronics (Oxford Univ. Press)

**Part of the Module: Organic Semiconductors (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 2

**Examination****Organic Semiconductors**

written exam / length of examination: 60 minutes, graded

**Examination Prerequisites:**

Organic Semiconductors

<b>Module PHM-0066: Superconductivity</b> <i>Superconductivity</i>		6 ECTS/LP
Version 1.0.0 (since WS11/12) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introductory Remarks and Literature</li> <li>• History and Main Properties of the Superconducting State, an Overview</li> <li>• Phenomenological Thermodynamics and Electrodynamics of the SC</li> <li>• Ginzburg-Landau Theory</li> <li>• Microscopic Theories</li> <li>• Fundamental Experiments on the Nature of the Superconducting State</li> <li>• Josephson-Effects</li> <li>• High Temperature Superconductors</li> <li>• Application of Superconductivity</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• will get an introduction to superconductivity,</li> <li>• by a presentation of experimental results they will learn the fundamental properties of the superconducting state,</li> <li>• are informed about the most important technical applications of superconductivity.</li> <li>• Special attention will be drawn to the basic concepts of the main phenomeno-logical and microscopic theories of the superconducting state, to explain the experimental observations.</li> <li>• For self-studies a comprehensive list of further reading will be supplied.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Physik IV – Solid-state physics</li> <li>• Theoretical physics I-III</li> </ul>		
<b>Frequency:</b> each summer semester not in summer term 2023	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Superconductivity</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- W. Buckel, Supraleitung, 5. Auflage (VCH, Weinheim, 1994)
- W. Buckel und R. Kleiner, Supraleitung, 6. Auflage (WILEY-VCH, Weinheim, 2004)
- M. Tinkham, Introduction to Superconductivity, 2nd Edition (McGraw-Hill, Inc., New York, 1996, Reprint by Dover Publications Inc. Miniola , 2004)
- Weitere Literatur wird in der Vorlesung angegeben

**Examination**

**Superconductivity**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Superconductivity

<b>Module PHM-0060: Low Temperature Physics</b> <i>Low Temperature Physics</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Properties of matter at low temperatures</li> <li>• Cryoliquids and superfluidity</li> <li>• Cryogenic engineering</li> <li>• Thermometry</li> <li>• Quantum transport, criticality and entanglement in matter</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic properties of matter at low temperatures and the corresponding experimental techniques,</li> <li>• have acquired the theoretical knowledge to perform low-temperature measurements,</li> <li>• and know how to experimentally investigate current problems in low-temperature physics.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Physik IV - Solid-state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Low Temperature Physics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		

**Contents:**

- Introduction (temperature scale, history of low temperature physics)
- Properties of matter at low temperatures (specific heat, thermal expansion, electrical resistance, thermal conductivity)
- Cryoliquids and superfluidity (nitrogen, hydrogen, 4-He and 3-He: phase diagrams, superfluidity)
- Cryogenic engineering (liquefaction of gases, helium cryostats, dilution refrigerator, adiabatic demagnetization, further techniques)
- Thermometry (primary and secondary thermometers at different temperature regimes)
- Quantum Matter (quantum Transport, Quantum phase transitions, Quantum spin liquids)

**Literature:**

C. Enss, S. Hunklinger, Tieftemperaturphysik (Springer)  
F. Pobell, Matter and Methods at Low Temperatures (Springer)

**Assigned Courses:**

**Low Temperature Physics** (lecture)

**Part of the Module: Low Temperature Physics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Assigned Courses:**

**Low Temperature Physics (Tutorial)** (exercise course)

**Examination**

**Low Temperature Physics**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Low Temperature Physics



<b>Module PHM-0114: Porous Functional Materials</b> <i>Porous Functional Materials</i>		6 ECTS/LP
Version 1.0.0 (since SS11 to WS22/23) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Overview and historical developments</li> <li>• Structural families of porous frameworks</li> <li>• Synthesis strategies</li> <li>• Adsorption and diffusion</li> <li>• Thermal analysis methods</li> <li>• Catalytic properties</li> <li>• Advanced applications and current trends</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students shall acquire knowledge about design principles and synthesis of porous functional materials,</li> <li>• broaden their capabilities to characterize porous solid state materials with special emphasis laid upon sorption and thermal analysis,</li> <li>• become introduced into typical technical applications of porous solids.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Remarks:</b> <b>This module and the exams for this module will be offered in WS 2022/23 for the last time !</b>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> participation in the course Materials Chemistry		<b>Credit Requirements:</b> one written examination, 90 min
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Porous Functional Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Contents:</b> see module description		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Paul A. Wright, Microporous Framework Solids (RSC Materials Monographs, 2008)</li> <li>• selected reviews and journal articles cited on the slides</li> </ul>		

**Examination**

**Porous Functional Materials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Porous Functional Materials

<b>Module PHM-0068: Spintronics</b> <i>Spintronics</i>		6 ECTS/LP
Version 1.7.0 (since SoSe14) Person responsible for module: PD Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Basic micromagnetic interactions (exchange, anisotropy, DMI, stray fields, external fields) and where they come from</li> <li>• Emergence of spin textures such as domain walls and bubbles/skyrmions</li> <li>• Torques acting on the local magnetization (magnetic field torque, current in-plane spin-transfer torque, spin-Hall effect and spin-orbit torques)</li> <li>• Switching</li> <li>• Motion of spin textures, 1D model and Thiele equation</li> <li>• Magneto-resistance and Hall effects and their utility in electrical readout</li> <li>• Ultrafast effects</li> <li>• Device applications</li> <li>• Experimental techniques in the field of spintronics</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the fundamental interactions in magnetic materials, the basic spintronic effects, and the related device structures,</li> <li>• have the competence to deal with current problems in the field of spintronics largely autonomously,</li> <li>• are able to choose materials in order to achieve demanding properties in spintronic applications,</li> <li>• are able to design device components to achieve spin polarization,</li> <li>• acquire scientific skills in finding and understanding current literature dealing with spintronic devices and applications, identifying suitable materials and material combinations with respect to their applicability for spintronic devices.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> every 3rd semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Spintronics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 3		

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- N. W. Ashcroft, N. D. Mermin, Solid State Physics, Cengage Learning (2011), ISBN: 81-315-0052-7
- C. Felser, G. H. Hechter, Spintronics - From Materials to Devices, Springer (2013), ISBN: 978-90-481-3831-9
- S. Bandyopadhyay, M. Cahay, Introduction to Spintronics, CRC Press (2008), ISBN: 978-0-9493-3133-6

**Part of the Module: Spintronics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 1

**Examination**

**Spintronics**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Spintronics

<b>Module PHM-0057: Physics of Thin Films</b> <i>Physics of Thin Films</i>		6 ECTS/LP
Version 1.6.0 (since WS09/10) Person responsible for module: PD Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Thin film growth: basics, thermodynamic considerations, surface kinetics, growth mechanisms</li> <li>Thin film growth techniques: vacuum technology, physical vapor deposition, chemical vapor deposition</li> <li>Analysis and characterization of thin films: in-sit methods, ex-situ methods, direct methods</li> <li>Properties and applications of thin films</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>know a broad spectrum of methods of thin film technology and material properties and applications of thin films,</li> <li>have the competence to deal with current problems in the field of thin film technology largely autonomous,</li> <li>are able to choose the right substrates and thin film materials for epitaxial thin film growth to achieve desired application conditions,</li> <li>acquire skills of combining the various technologies for growing thin layers with respect to their properties and applications, and</li> <li>acquire scientific soft skills to search for scientific literature, understand technical english, work with literature in the field of thin films, interpret experimental results.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> every 3rd semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Physics of Thin Films****Mode of Instruction:** lecture**Language:** English**Frequency:** each winter semester**Contact Hours:** 4**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- H. Frey, G. Kienel, Dünnschichttechnologie (VDI Verlag, 1987)
- H. Lüth, Solid Surfaces, Interfaces and Thin Films (Springer Verlag, 2001)
- A. Wagendristel, Y. Wang, An Introduction to Physics and Technology of Thin Films (World Scientific Publishing, 1994)
- M. Ohring, The Materials Science of Thin Films (Academic Press, 1992)

**Examination**

**Physics of Thin Films**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Physics of Thin Films

<b>Module PHM-0056: Ion-Solid Interaction</b> <i>Ion-Solid Interaction</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction (areas of scientific and technological application, principles)</li> <li>• Fundamentals of atomic collision processes (scattering, cross-sections, energy loss models, potentials in binary collision models)</li> <li>• Ion-induced modification of solids (integrated circuit fabrication with emphasis on ion induced phenomena, ion implantation, radiation damage, ion milling and etching (RIE), sputtering, erosion, deposition)</li> <li>• Transport phenomena</li> <li>• Analysis with ion beams</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the physical principles and the basic mechanisms of the interaction between particles and solid state bodies in the energy range of eV to MeV,</li> <li>• are able to choose adequate physical models for specific technological and scientific applications, and</li> <li>• have the competence to work extensively autonomous on problems concerning the interaction between ions and solid state bodies.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic Courses in Physics I–IV, Solid State Physics, Nuclear Physics		
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Ion-Solid Interaction</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- R. Smith, Atomic and ion collisions in solids and at surfaces (Cambridge University Press, 1997)
- E. Rimini, Ion implantation: Basics to device fabrication (Kluwer, 1995)
- W. Eckstein: Computer Simulation of Ion-Solid Interactions (Springer, 1991)
- H. Ryssel, I. Ruge: Ionenimplantation (Teubner, 1978)
- Y. H. Ohtsuki: Charged Beam Interaction with Solids (Taylor & Francis, 1983)
- J. F. Ziegler (Hrsg.): The Stopping and Range of Ions in Solids (Pergamon)
- R. Behrisch (Hrsg.): Sputtering by Particle Bombardment (Springer)
- M. Nastasi, J. K. Hirvonen, J. W. Mayer: Ion-Solid Interactions: Fundamentals and Applications (Cambridge University Press, 1996)
- <http://www.SRIM.org>

**Part of the Module: Ion-Solid Interaction (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Ion-Solid Interaction**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Ion-Solid Interaction



<b>Module PHM-0069: Applied Magnetic Materials and Methods</b> <i>Applied Magnetic Materials and Methods</i>		6 ECTS/LP
Version 1.1.0 (since WS14/15) Person responsible for module: Prof. Dr. Manfred Albrecht		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Basics of magnetism</li> <li>• Ferrimagnets, permanent magnets</li> <li>• Magnetic nanoparticles</li> <li>• Superparamagnetism</li> <li>• Exchange bias effect</li> <li>• Magnetoresistance, sensors</li> <li>• Experimental methods (e.g. Mößbauer Spectroscopy, mu-SR)</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic terms and concepts of magnetism,</li> <li>• get a profound understanding of basic physical relations and their applications,</li> <li>• acquire the ability to describe qualitative observations, interpret quantitative measurements, and develop mathematical descriptions of physical effects of chosen magnetic material systems.</li> <li>• Integrated acquirement of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basics in solid state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Applied Magnetic Materials and Methods</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> Stephan Bundell, Magnetism in Condensed Matter, Oxford University Press, ISBN: 0-19-850591-4 (Pbk) J.M.C. Coey, Magnetism and Magnetic Materials, Cambridge University Press, ISBN: 978-0-521-81614-4 (hardback)		

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**Part of the Module: Applied Magnetic Materials and Methods (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Applied Magnetic Materials and Methods**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Applied Magnetic Materials and Methods

<b>Module PHM-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons</b> <i>Solid State Spectroscopy with Synchrotron Radiation and Neutrons</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. Christine Kuntscher		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Electromagnetic radiation: description, generation, detection [5]</li> <li>2. Spectral analysis of electromagnetic radiation: monochromators, spectrometer, interferometer [2]</li> <li>3. Excitations in the solid state: Dielectric function [2]</li> <li>4. Infrared spectroscopy</li> <li>5. Ellipsometry</li> <li>6. Photoemission spectroscopy</li> <li>7. X-ray absorption spectroscopy</li> <li>8. Neutrons: Sources, detectors</li> <li>9. Neutron scattering</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basics of spectroscopy and important instrumentation and methods,</li> <li>• have acquired the skills of formulating a mathematical-physical ansatz in spectroscopy and can apply these in the field of solid state spectroscopy,</li> <li>• have the competence to deal with current problems in solid state spectroscopy autonomously, and are able to judge proper measurement methods for application.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> basic knowledge in solid-state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- H. Kuzmany, Solid State Spectroscopy (Springer)
- N. W. Ashcroft, N. D. Mermin, Solid State Physics (Holt, Rinehart and Winston)
- J. M. Hollas, Modern Spectroscopy

**Assigned Courses:**

**Solid State Spectroscopy with Synchrotron Radiation and Neutrons** (lecture)

**Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Assigned Courses:**

**Solid State Spectroscopy with Synchrotron Radiation and Neutrons (Tutorial)** (exercise course)

**Examination**

**Solid State Spectroscopy with Synchrotron Radiation and Neutrons**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Solid State Spectroscopy with Synchrotron Radiation and Neutrons

<b>Module PHM-0051: Biophysics and Biomaterials</b> <i>Biophysics and Biomaterials</i>		6 ECTS/LP
Version 1.1.0 (since SoSe22) Person responsible for module: Dr. Stefan Thalhammer Westerhausen, Christoph, Dr.		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Transcription and translation</li> <li>• Membranes</li> <li>• DNA and proteins</li> <li>• Enabling technologies</li> <li>• Microfluidics</li> <li>• Radiation Biophysics</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students know: <ul style="list-style-type: none"> <li>• basic terms, concepts and phenomena of biological physics</li> <li>• models of the (bio)polymer-theory, microfluidics, radiation biophysics, nanobiotechnology, sequencing strategies, membranes and proteins</li> </ul> The students obtain skills <ul style="list-style-type: none"> <li>• for independent processing of problems and dealing with current literature.</li> <li>• to translate a biological observation into a physical question.</li> </ul> The students improve the key competences: <ul style="list-style-type: none"> <li>• self-dependent working with English specialist literature.</li> <li>• processing and interpretation of experimental data.</li> <li>• interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study)		
<b>Conditions:</b> Mechanics, Thermodynamics, Statistical Physics		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Biophysics and Biomaterials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Learning Outcome:**

See module description.

**Contents:**

- Radiation Biophysics
  - Radiation sources
  - Interaction of radiation with biological matter
  - Radiation protection principles
  - Low dose radiation
  - LNT model in radiation biophysics
- Microfluidics
  - Life at Low Reynolds Numbers
  - The Navier-Stokes Equation
  - Low Reynolds Numbers – The Stokes Equation
  - Breaking the Symmetry
- Membranes
  - Thermodynamics and Fluctuations
  - Thermodynamics of Interfaces
  - Phase Transitions – 2 state model
  - Lipid membranes and biological membranes, membrane elasticity
- Membranal transport
  - Random walk, friction and diffusion
  - Transmembranal ionic transport and ion channels
  - Electrophysiology of cells
  - Neuronal Dynamics

**Literature:**

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle, R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- lecture notes

**Part of the Module: Biophysics and Biomaterials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

See module description.

**Examination**

**Biophysics and Biomaterials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Biophysics and Biomaterials

<b>Module PHM-0059: Magnetism</b> <i>Magnetism</i>		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Dr. Hans-Albrecht Krug von Nidda		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• History, basics</li> <li>• Magnetic moments, classical and quantum phenomenology</li> <li>• Exchange interaction and mean-field theory</li> <li>• Magnetic anisotropy and magnetoelastic effects</li> <li>• Thermodynamics of magnetic systems and applications</li> <li>• Magnetic domains and domain walls</li> <li>• Magnetization processes and micro magnetic treatment</li> <li>• AC susceptibility and ESR</li> <li>• Spintransport / spintronics</li> <li>• Recent problems of magnetism</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic properties and phenomena of magnetic materials and the most important methods and concepts for their description, like mean-field theory, exchange interactions and micro magnetic models,</li> <li>• have the ability to classify different magnetic phenomena and to apply the corresponding models for their interpretation, and</li> <li>• have the competence independently to treat fundamental and typical topics and problems of magnetism.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> basics of solid-state physics and quantum mechanics		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Magnetism</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- D. H. Martin, Magnetism in Solids (London Iliffe Books Ltd.)
- J. B. Goodenough, Magnetism and the Chemical Bond (Wiley)
- P. A. Cox, Transition Metal Oxides (Oxford University Press)
- C. Kittel, Solid State Physics (Wiley)
- D. C. Mattis, The Theory of Magnetism (Wiley)
- G. L. Squires, Thermal Neutron Scattering (Dover Publications Inc.)

**Part of the Module: Magnetism (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Magnetism**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Magnetism



<b>Module PHM-0048: Physics and Technology of Semiconductor Devices</b> <i>Physics and Technology of Semiconductor Devices</i>		6 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> 1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport) 2. Semiconductor diodes and transistors 3. Semiconductor technology		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport.</li> <li>• Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors.</li> <li>• Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes and transistors</li> <li>• Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication.</li> <li>• Integrated acquisition of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid state physics, statistical physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Physics and Technology of Semiconductor Devices</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- Yu und Cardona: Fundamentals of Semiconductors (Springer)
- Sze: Physics of Semiconductor Devices (Wiley)
- Sze: Semiconductor Devices (Wiley)
- Madelung: Halbleiterphysik (Springer)
- Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)

**Part of the Module: [Physics and Technology of Semiconductor Devices \(Tutorial\)](#)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

see module description

**Examination**

**Physics and Technology of Semiconductor Devices**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Physics and Technology of Semiconductor Devices

<b>Module PHM-0049: Nanostructures / Nanophysics</b> <i>Nanostructures / Nanophysics</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. István Kézsmárki		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Semiconductor quantum wells, wires and dots, low dimensional electron systems</li> <li>2. Magnetotransport in low-dimensional systems, Quantum-Hall-Effect, Quantized conductance</li> <li>3. Optical properties of nanostructures and their application in modern optoelectronic devices, Nanophotonics</li> <li>4. Fabrication and detection techniques of nanostructures</li> <li>5. Ferroic properties of nanostructures (Ferroelectricity, Magnetism, Multiferroicity)</li> <li>6. Nano-bio-magnetism (magnetotactic bacteria, magnetoreception, malaria)</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students gain basic knowledge of the fundamental concepts in modern nanoscale science.</li> <li>• The students have detailed knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics</li> <li>• The students gain competence in selecting different fabrication and characterization approaches for specific nanostructures.</li> <li>• The students are able apply these concepts to tackle present problems in nanophysics.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Nanostructures / Nanophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- Yu und Cardona: Fundamentals of Semiconductors
- Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)
- Davies: The Physics of low-dimensional Semiconductors (Cambridge University Press)

**Examination**

**Nanostructures / Nanophysics**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

Nanostructures / Nanophysics

<b>Module PHM-0054: Chemical Physics II</b> <i>Chemical Physics II</i>		6 ECTS/LP
Version 1.4.0 (since WS09/10 to WS22/23) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to computational chemistry</li> <li>• Hartree-Fock Theory</li> <li>• DFT in a nutshell</li> <li>• Prediction of reaction mechanisms</li> <li>• calculation of physical and chemical properties</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic quantum chemical methods of chemical physics to interpret the electronic structures in molecules and solid-state compounds,</li> <li>• have therefore the competence to autonomously perform simple quantum chemical calculations using Hartree-Fock and Density Functional Theory (DFT) and to interpret the electronic structure of functional molecules and materials with regard to their chemical and physical properties</li> <li>• Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.</li> </ul>		
<b>Remarks:</b> It is possible for students to do quantum chemical calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> It is highly recommended to complete the module Chemical Physics I first.		
<b>Frequency:</b> each summer semester not in summer term 23	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Chemical Physics II</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		

**Literature:**

- I. N. Levine, Quantum Chemistry, Pearson, 7th ed **2013**.
- A. Szabo, N. S. Ostlund, Modern Quantum Chemistry, Dover, **1996** (EbookCentral ebook).
- E. G. Lewars, Computational Chemistry, Springer, **2011**.
- D. C. Young, Computational Chemistry: A practical guide for applying techniques to real world problems, Wiley ebook, **2002**.
- R. A. van Santen, Ph. Sautet, Computational Methods in Catalysis and Materials Science, Wiley ebook, **2009**.
- P. Popelier, Atoms in Molecules: An Introduction, Pearson Education Limited, **2000**.
- A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc. Pittsburg, PA.

**Part of the Module: Chemical Physics II (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Learning Outcome:**

see module description

**Examination**

**Chemical Physics II**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Chemical Physics II

<b>Module PHM-0113: Advanced Solid State Materials</b> <i>Advanced Solid State Materials</i>		6 ECTS/LP
Version 1.2.0 (since WS10/11) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Repitition of concepts</li> <li>• Novel silicate-analogous materials</li> <li>• Luminescent materials</li> <li>• Pigments</li> <li>• Heterogeneous catalysis</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are aware of correlations between composition, structures and properties of functional materials,</li> <li>• acquire skills to predict the properties of chemical compounds, based on their composition and structures,</li> <li>• gain competence to evaluate the potential of functional materials for future technological developments, and</li> <li>• will know how to measure the properties of these materials.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Contents of the modules Chemie I, and Chemie II or Festkörperchemie (Bachelor Physik, Bachelor Materialwissenschaften)		
<b>Frequency:</b>	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Advanced Solid State Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3
<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Literature:</b> <ul style="list-style-type: none"> <li>• A. West, Solid State Chemistry and Its Applications</li> <li>• L. Smart, E. Moore, Solid State Chemistry</li> <li>• Scripts Solid State Chemistry and Chemistry I and II</li> </ul>

**Part of the Module: Advanced Solid State Materials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

see module description

**Literature:**

- A. West, Solid State Chemistry and Its Applications
- L. Smart, E. Moore, Solid State Chemistry
- Scripts Solid State Chemistry and Chemistry I and II

**Examination**

**Advanced Solid State Materials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Advanced Solid State Materials



<b>Module PHM-0218: Novel Methods in Solid State NMR Spectroscopy</b> <i>Novel Methods in Solid State NMR Spectroscopy</i>		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
<b>Contents:</b> The physical basis of nuclear magnetic resonance Pulsed NMR methods; Fourier Transform NMR Internal interactions Magic Angle Spinning Modern pulse sequences or how to obtain specific information about the structure and dynamics of solid materials Recent highlights of the application of modern solid state NMR in materials science		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Novel Methods in Solid State NMR Spectroscopy</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 3		
<b>Assigned Courses:</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> (lecture)		
<b>Part of the Module: Novel Methods in Solid State NMR Spectroscopy (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Contact Hours:</b> 1		
<b>Literature:</b> 1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008. 2. H. Günther, NMR spectroscopy, Wiley 2001. 3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004. 4. D. Canet: NMR - concepts and methods, Springer, 1994.		
<b>Assigned Courses:</b> <b>Novel Methods in Solid State NMR Spectroscopy (Tutorial)</b> (exercise course)		
<b>Examination</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> written exam / length of examination: 90 minutes, graded		

<b>Module PHM-0167: Oxidation and Corrosion</b> <i>Oxidation and Corrosion</i>	6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider	
<p><b>Contents:</b></p> Introduction Review of thermodynamics Chemical equilibria Electrochemistry Electrode kinetics High temperature oxidation Localized corrosion <ul style="list-style-type: none"> <li>• Shallow pit corrosion</li> <li>• Pitting corrosion</li> <li>• Crevice corrosion</li> <li>• Intercrystalline corrosion</li> <li>• Stress corrosion cracking</li> <li>• Fatigue corrosion</li> <li>• Erosion corrosion</li> <li>• Galvanic corrosion</li> </ul> Water and seawater corrosion Corrosion monitoring Corrosion properties of specific materials Specific corrosion problems in certain branches <ul style="list-style-type: none"> <li>• Oil and Gas industry</li> <li>• Automobile industry</li> <li>• Food industry</li> </ul> Corrosion protection <ul style="list-style-type: none"> <li>• Passive layers</li> <li>• Reaction layers (Diffusion layers ...)</li> <li>• Coatings (organic, inorganic)</li> <li>• Cathodic, anodic protection</li> <li>• Inhibitors</li> </ul>	
<p><b>Learning Outcomes / Competences:</b></p> The students: <ul style="list-style-type: none"> <li>• know the the fundamental basics, mechanics, types of corrosion processes and their electrochemical explanation</li> <li>• obtain the skill to understand typical electrochemical quantification of corrosion processes.</li> <li>• acquire the competence to assess corrosion phenomena from typical damage patterns</li> </ul>	
<p><b>Remarks:</b></p> Scheduled every second summer semester.	
<p><b>Workload:</b></p> Total: 180 h 60 h lecture and exercise course (attendance)	

120 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: good knowledge in materials science, basic knowledge in physical chemistry		<b>Credit Requirements:</b> written exam (90 min)
<b>Frequency:</b> each summer semester alternating with PHM-0168	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Oxidation and Corrosion****Mode of Instruction:** lecture**Language:** English**Frequency:** each winter semester**Contact Hours:** 3**Literature:**

- Schütze: Corrosion and Environmental Degradation

**Assigned Courses:****Oxidation and Corrosion** (lecture)**Part of the Module: Oxidation and Corrosion (Tutorial)****Mode of Instruction:** exercise course**Language:** English**Frequency:** each winter semester**Contact Hours:** 1**Assigned Courses:****Oxidation and Corrosion (Tutorial)** (exercise course)**Examination****Oxidation and Corrosion**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Oxidation and Corrosion

<b>Module PHM-0164: Characterization of Composite Materials</b> <i>Characterization of Composite Materials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Markus Sause		
<b>Contents:</b> The following topics are presented: <ul style="list-style-type: none"> <li>• Introduction to composite materials</li> <li>• Applications of composite materials</li> <li>• Mechanical testing</li> <li>• Thermophysical testing</li> <li>• Nondestructive testing</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• acquire knowledge in the field of materials testing and evaluation of composite materials.</li> <li>• are introduced to important concepts in measurement techniques, and material models applied to composites.</li> <li>• are able to independently acquire further information of the scientific topic using various forms of information.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in materials science, particularly in composite materials		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Characterization of Composite Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Morgan: Carbon fibers and their composites</li> <li>• Henning, Moeller: Handbuch Leichtbau</li> <li>• Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden</li> <li>• Neitzel, Mitschang: Handbuch Verbundwerkstoffe</li> <li>• Dowling: Mechanical behaviour of materials</li> <li>• Issler: Festigkeitslehre - Grundlagen</li> <li>• Landau, Lifschitz: Theoretische Physik Vol. 7</li> </ul> <p>Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.</p>

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**Part of the Module: Characterization of Composite Materials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Literature:**

see lecture

**Examination**

**Characterization of Composite Materials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Characterization of Composite Materials

<b>Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties</b> <i>Fiber Reinforced Composites: Processing and Materials Properties</i>		6 ECTS/LP
Version 1.2.0 (since SoSe15) Person responsible for module: Dr. Judith Moosburger-Will		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Production of fibers (e.g. glass, carbon, or ceramic fibers)</li> <li>• Physical and chemical properties of fibers and their precursor materials</li> <li>• Physical and chemical properties of commonly used polymeric and ceramic matrix materials</li> <li>• Semi-finished products</li> <li>• Composite production technologies</li> <li>• Application of fiber reinforced materials</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the physical and chemical properties of fibers, matrices, and fiber-reinforced materials.</li> <li>• know the basics of production technologies of fibers, polymeric, ceramic matrices, and fiber-reinforced materials.</li> <li>• know the application areas of composite materials.</li> <li>• have the competence to explain material properties of fibers, matrices, and composites.</li> <li>• have the competence to choose the right materials according to application relevant conditions.</li> <li>• are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge in materials science, basic lectures in organic chemistry		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Literature:**

- Morgan: Carbon fibers and their composites
- Ehrenstein: Polymeric materials
- Krenkel: Ceramic Matrix Composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

**Assigned Courses:**

**Fiber Reinforced Composites: Processing and Materials Properties** (lecture)

**Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Literature:**

see lecture

**Assigned Courses:**

**Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)** (exercise course)

**Examination**

**Fiber Reinforced Composites: Processing and Materials Properties**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Fiber Reinforced Composites: Processing and Materials Properties

<b>Module PHM-0165: Introduction to Mechanical Engineering</b> <i>Introduction to Mechanical Engineering</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Dr. - Ing. Johannes Schilp		
<b>Contents:</b> The following topics are treated: <ul style="list-style-type: none"> <li>• Statics and dynamics of objects</li> <li>• Transmissions and mechanisms</li> <li>• Tension, shear and bending moment</li> <li>• Hydrostatics</li> <li>• Hydrodynamics</li> <li>• Strength of materials and solid mechanics</li> <li>• Instrumentation and measurement</li> <li>• Mechanical design (including kinematics and dynamics)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students understand and are able to apply basic concepts of physics and materials science to: <ul style="list-style-type: none"> <li>• Engineering applications</li> <li>• Mechanical testing</li> <li>• Instrumentation</li> <li>• Mechanical design</li> </ul>		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Mechanical Engineering</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Part of the Module: Mechanical Engineering (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Contact Hours:</b> 1		
<b>Examination</b> <b>Introduction to Mechanical Engineering</b> written exam / length of examination: 90 minutes, graded <b>Examination Prerequisites:</b> Introduction to Mechanical Engineering		



<b>Module MRM-0052: Functional Polymers</b>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: PD Dr. Klaus Ruhland		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to polymer science</li> <li>• Elastomers and elastoplastic materials</li> <li>• Memory-shape polymers</li> <li>• Piezoelectric polymers</li> <li>• Electrically conducting polymers</li> <li>• Ion-conducting polymers</li> <li>• Magnetic polymers</li> <li>• Photoresponsive polymers</li> <li>• Polymers with second order non-linear optical properties</li> <li>• Polymeric catalysts</li> <li>• Self-healing polymers</li> <li>• Polymers in bio sciences&gt;</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students learn how polymeric materials can be designed and applied to act in a smart manner on an external mechanical, magnetic, electric, optical, thermal or chemical impact.		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: Attendance to PHM-0035 (Chemie I), PHM-0036 (Chemie II) and MRM-0050 (Grundlagen der Polymerchemie und -physik)		
<b>Frequency:</b> irregular will not be offered in the next time	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>		
<b>Part of the Module: Functional Polymers</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Part of the Module: Functional Polymers (Tutorial)</b>		
<b>Mode of Instruction:</b> exercise course		
<b>Language:</b> English		
<b>Frequency:</b> each summer semester		
<b>Contact Hours:</b> 1		

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**Examination**

**Functional Polymers**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Functional Polymers

<b>Module PHM-0168: Modern Metallic Materials</b> <i>Modern Metallic Materials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Introduction Review of physical metallurgy Steels: <ul style="list-style-type: none"> <li>• principles</li> <li>• common alloying elements</li> <li>• martensitic transformations</li> <li>• dual phase steels</li> <li>• TRIP and TWIP steels</li> <li>• maraging steel</li> <li>• electrical steel</li> <li>• production and processing</li> </ul> Aluminium alloys: <ul style="list-style-type: none"> <li>• 2xxx</li> <li>• 6xxx</li> <li>• 7xxx</li> <li>• Processing – creep forming, hydroforming, spinforming</li> </ul> Titanium alloys Magnesium alloys Superalloys Intermetallics, high entropy alloys		
<b>Learning Outcomes / Competences:</b> Students <ul style="list-style-type: none"> <li>• learn about relevant classes of actual metallic alloys and their properties</li> <li>• acquire the skill to derive alloy properties from physical metallurgy principles and concepts</li> <li>• have the competence to choose and to explain appropriate metallic materials for special applications</li> </ul>		
<b>Remarks:</b> Scheduled every second summer semester.		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: Knowledge of physical metallurgy and physical chemistry		
<b>Frequency:</b> each summer semester alternating with PHM-0167	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

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**Parts of the Module**

**Part of the Module: Modern Metallic Materials**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 4

**Literature:**

Cahn-Haasen-Kramer: Materials Science and Technology

Original literature

**Examination**

**Modern Metallic Materials**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Modern Metallic Materials

<b>Module PHM-0196: Surfaces and Interfaces II: Joining processes</b> <i>Surfaces and Interfaces II: Joining processes</i>		6 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Dr. Judith Moosburger-Will		
<b>Learning Outcomes / Competences:</b> The students - know the application areas of composite materials - know the basics of cohesion and adhesion - know the basics of joining techniques - are introduced to physical and chemical properties metal-metal, metal-polymer and polymer-polymer interfaces - Are able to independently acquire further knowledge of the scientific topic using various forms of information.		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> Basic knowledge on materials science, lecture "Surfaces and Interfaces I" Module Surfaces and Interfaces (PHM-0117) - recommended		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> any	

<b>Parts of the Module</b>
<b>Part of the Module: Surfaces and Interfaces II: Joining processes</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Siegfried Horn <b>Language:</b> German <b>Contact Hours:</b> 3
<b>Contents:</b> The following topics are treated: - Introduction to adhesion - Role of surface and interface properties - Introduction to interactions at surfaces and interfaces - Adhesion theories - Surface and interface energy - Surface treatment techniques - Joining techniques - Physical and chemical properties of joints - Applications
<b>Lehr-/Lernmethoden:</b> Lecture: Beamer presentation and Blackboard Exercise: Exercises on recent topics, specialization of lecture contents
<b>Literature:</b> Literature, including actual scientific papers and reviews, will be announced at the beginning of the lecture.

**Examination**

**Surfaces and Interfaces II: Joining processes**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Surfaces and Interfaces II: Joining processes

**Parts of the Module**

**Part of the Module: Übung zu Surfaces and Interfaces II: Joining processes**

**Mode of Instruction:** exercise course

**Language:** German

**Contact Hours:** 1

<b>Module PHM-0122: Non-Destructive Testing</b> <i>Non-Destructive Testing</i>		6 ECTS/LP
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Markus Sause		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to nondestructive testing methods</li> <li>• Visual inspection</li> <li>• Ultrasonic testing</li> <li>• Guided wave testing</li> <li>• Acoustic emission analysis</li> <li>• Thermography</li> <li>• Radiography</li> <li>• Eddy current testing</li> <li>• Specialized nondestructive methods</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• acquire knowledge in the field of nondestructive evaluation of materials,</li> <li>• are introduced to important concepts in nondestructive measurement techniques,</li> <li>• are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Basic knowledge on materials science, in particular composite materials		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Non-Destructive Testing</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

- Raj: Practical Non-destructive Testing
- Shull: Nondestructive Evaluation - Theory and Applications
- Krautkrämer: Ultrasonic testing of materials
- Grosse: Acoustic Emission Testing
- Rose: Ultrasonic waves in solid media
- Maldague: Nondestructive Evaluation of Materials by Infrared Thermography
- Herman: Fundamentals of Computerized Tomography

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

**Assigned Courses:**

**Non-Destructive Testing** (lecture)

**Part of the Module: Non-Destructive Testing (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Assigned Courses:**

**Non-Destructive Testing (Tutorial)** (exercise course)

**Examination**

**Non-Destructive Testing**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Non-Destructive Testing



<b>Module PHM-0203: Physics of Cells</b> <i>Physics of Cells</i>		6 ECTS/LP
Version 1.3.0 (since SoSe22) Person responsible for module: Dr. Christoph Westerhausen		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Physical principles in Biology</li> <li>Cell components and their material properties: cell membrane, organelles, cytoskeleton</li> <li>Thermodynamics of proteins and biological membranes</li> <li>Physical methods and techniques for studying cells</li> <li>Cell adhesion – interplay of specific, universal and elastic forces</li> <li>Tensile strength and elasticity of tissue - macromolecules of the extra cellular matrix</li> <li>Micro mechanics and properties of the cell as a biomaterial</li> <li>Cell adhesion</li> <li>Cell migration</li> <li>Cell actuation, cell-computer-communication, and cell stimulation</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>know basic physical properties of human cells, as building blocks of living organisms and their material properties.</li> <li>know the basic functionality of mechanical and optical methods to study living cells</li> <li>know physical descriptions of fundamental biological processes and properties of biomaterials.</li> <li>are able to express biophysical questions and define model systems to answer these questions.</li> </ul> The students improve the key competences: <ul style="list-style-type: none"> <li>self-dependent working with English specialist literature.</li> <li>processing of experimental data.</li> <li>interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Mechanics, Thermodynamics		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Physics of Cells</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English / German		
<b>Contact Hours:</b> 2		
<b>Learning Outcome:</b> see module description		

<p><b>Contents:</b> see module description</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Sackmann, Erich, and Rudolf Merkel. <i>Lehrbuch der Biophysik</i>. Wiley-VCH, 2010.</li> <li>• Heimburg, Thomas. <i>Thermal Biophysics of Membranes</i>. Wiley-VCH, 2007</li> <li>• Nelson, Philip. <i>Biological physics</i>. New York: WH Freeman, 2004.</li> <li>• Boal, D. <i>Mechanics of the Cell</i>. Cambridge University Press, 2012</li> <li>• Lecture notes</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Physics of Cells</b> (lecture)</p>
<p><b>Part of the Module: Physics of Cells (Tutorial)</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> English / alle Sprachen  <b>Contact Hours:</b> 2</p>
<p><b>Learning Outcome:</b> see module description</p>
<p><b>Contents:</b> see module description</p>
<p><b>Literature:</b> see module description</p>
<p><b>Assigned Courses:</b></p> <p><b>Physics of Cells (Tutorial)</b> (exercise course)</p>
<p><b>Examination</b></p> <p><b>Physics of Cells</b> oral exam / length of examination: 30 minutes, graded</p>

<b>Module PHM-0217: Advanced X-ray and Neutron Diffraction Techniques</b> <i>Advanced X-ray and Neutron Diffraction Techniques</i>		6 ECTS/LP
Version 1.3.0 (since SoSe17 to SoSe23) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<b>Contents:</b> Subjects of the lecture are advanced X-ray and neutron diffraction techniques: <ul style="list-style-type: none"> <li>• The failure of the standard <i>Independent Atom Model</i> (IAM) in X-ray diffraction</li> <li>• Beyond the standard model: The multipolar model</li> <li>• How to obtain and analyze experimental charge densities</li> <li>• How to derive chemical and physical properties from diffraction data</li> <li>• Applications of joined X-ray and neutron diffraction experiments</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• gain basic theoretical knowledge on the reconstruction of accurate electron density maps from X-ray and neutron diffraction data</li> <li>• know the basics of the <i>Quantum Theory of Atoms in Molecules</i></li> <li>• are competent to analyze the topology of the electron density and correlate it with the physical and chemical properties of materials</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> It is recommended to complete the Module PHM-0053 Chemical Physics I.		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Advanced X-ray and Neutron Diffraction Techniques</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Literature:**

1. C. Giacovazzo et al., Fundamentals of Crystallography, Oxford Univ. Press, 2011.
2. P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.
3. P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.
4. P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.
5. P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.

**Part of the Module: Advanced X-ray and Neutron Diffraction Techniques (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Advanced X-ray and Neutron Diffraction Techniques**

written exam / length of examination: 90 minutes, graded

**Examination Prerequisites:**

Advanced X-ray and Neutron Diffraction Techniques

<b>Module PHM-0146: Method Course: Electronics for Physicists and Materials Scientists</b> <i>Method Course: Electronics for Physicists and Materials Scientists</i>		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering</li> <li>2. Quadrupole theory</li> <li>3. Analog technique, transistor and opamp circuits</li> <li>4. Boolean algebra and logic</li> <li>5. Digital electronics and calculation circuits</li> <li>6. Microprocessors and Networks</li> <li>7. Basics in Electronic</li> <li>8. Implementation of transistors</li> <li>9. Operational amplifiers</li> <li>10. Digital electronics</li> <li>11. Practical circuit arrangement</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the laboratory,</li> <li>• have skills in easy circuit design, measuring and control technology, analog and digital electronics,</li> <li>• have expertise in independent working on circuit problems. They can calculate and develop easy circuits.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b> Attendance in the <b>Method Course: Electronics for Physicists and Materials Scientists (combined lab course AND lecture)</b> excludes credit points for the lecture <b>Electronics for Physicists and Materials Scientists</b> .		
<b>Workload:</b> Total: 240 h 140 h studying of course content using provided materials (self-study) 60 h lecture (attendance) 10 h preparation of written term papers (self-study) 30 h internship / practical course (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> written report (one per group)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		

**Literature:**

- Paul Horowitz: The Art of Electronics (Cambridge University Press)
- National Instruments: MultiSim software package (available in lecture)

**Assigned Courses:**

**Method Course: Electronics for Physicists and Materials Scientists** (lecture)

**Part of the Module: Method Course: Electronics for Physicists and Materials Scientists (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 2

**Assigned Courses:**

**Method Course: Electronics for Physicists and Materials Scientists (Practical Course)** (internship)

**Examination**

**Method Course: Electronics for Physicists and Materials Scientists**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

each semester

<b>Module PHM-0147: Method Course: Electron Microscopy</b> <i>Method Course: Electron Microscopy</i>		8 ECTS/LP
Version 1.3.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Scanning electron microscopy (SEM) <ul style="list-style-type: none"> <li>• Electron optical components</li> <li>• Detectors</li> <li>• EDX, EBSD</li> </ul> Transmission electron microscopy (TEM) <ul style="list-style-type: none"> <li>• Diffraction</li> <li>• Contrast mechanisms</li> <li>• High resolution EM</li> <li>• Scanning TEM</li> <li>• Analytical TEM</li> <li>• Aberration correction</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• get introduced to the basics of scanning electron microscopy and transmission electron microscopy, using lectures to teach the theoretical basics, which are afterwards deepened using practical courses,</li> <li>• are able to operate SEM and TEM on a basic level</li> <li>• are able to characterize materials using different electron microscopy techniques</li> <li>• Acquire the competence to decide about a technique feasible for a certain problem.</li> <li>• acquire the competence to assess EM images, also regarding artefacts</li> <li>• learn to search for scientific literature and to formulate a scientific report</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 150 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: knowledge of solid-state physics, reciprocal lattice		<b>Credit Requirements:</b> regular participation, oral presentation (10 min), written report (one report per group)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Electron Microscopy</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

**Contents:**

SEM:

1. Layout of Electron Microscopes and Electron Optical Components
2. Electron Solid Interactions
3. Contrast Formation in Scanning Electron Microscopy (SEM)
4. SE/BSE contrast
5. Electron Back Scattering Diffraction (EBSD)
6. Analytical techniques
7. Special Applications of SEM

TEM:

1. TEM specimen preparation techniques
2. Components of a TEM, principle lens design, lens aberrations
3. Electron diffraction: fundamentals
4. Contrast formation at bright field, dark field, weak beam dark field, and many beam conditions, „chemical“ imaging
5. Bright field, dark field, weak beam dark field imaging of dislocations
6. Kinematical theory of electron wave propagation in crystals
7. Howie Whelan equations, contrast of defects
8. High resolution TEM, lattice imaging of crystals
9. Advanced diffraction techniques: Kikuchi patterns, HOLZ lines and Convergent Beam Diffraction (CBED)
10. Image simulation
11. Analytical TEM: Electron energy loss spectroscopy & energy filtered TEM

**Literature:**

- D.B.Williams and C.B.Carter, Transmission Electron Microscopy, Plenum Press, New York/London, 1996
- M.A. Hirsch, A. Howie, R. Nicholson, D.W. Pashley, M.J. Whelan, Electron microscopy of thin crystals, Krieger Publishing Company, Malabar (Florida), 1977
- L. Reimer, Transmission electron microscopy, Springer Verlag, Berlin/Heidelberg/New York, 1984
- P.J. Goodhew, Thin foil preparation for electron microscopy, Elsevier, Amsterdam, 1985
- P.R. Buseck, J.M. Cowley, L. Eyring, High-resolution transmission electron microscopy, Oxford University Press, 1988
- E. Hornbogen, B. Skrotzki, Werkstoff-Mikroskopie, Springer Verlag, Berlin/Heidelberg/New York, 1995
- K. Wetzig, In situ scanning electron microscopy in materials research, Akad.-Verl., 1995
- J. I. Goldstein, Scanning electron microscopy and x-ray microanalysis, Plenum Press, 1992
- L. Reimer, Scanning electron microscopy, Springer Verlag, 1985
- S. L. Flegler, J. W. Heckman, K. L. Klomparens, Elektronenmikroskopie, Spektrum, Akad. Verl., 1995

**Part of the Module: Method Course: Electron Microscopy (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Examination**

**Method Course: Electron Microscopy**

report, graded

**Examination Prerequisites:**

Method Course: Electron Microscopy



<b>Module PHM-0148: Method Course: Optical Properties of Solids</b> <i>Method Course: Optical Properties of Solids</i>		8 ECTS/LP
Version 1.4.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
<b>Contents:</b> Electrodynamics of solids <ul style="list-style-type: none"> <li>• Maxwell equations</li> <li>• Electromagnetic waves</li> <li>• Refraction and interference, Fresnel equations</li> </ul> FTIR spectroscopy <ul style="list-style-type: none"> <li>• Fourier transformation</li> <li>• Michelson-Morley and Genzel interferometer</li> <li>• Sources and detectors</li> </ul> Terahertz Time Domain spectroscopy <ul style="list-style-type: none"> <li>• Generation of pulsed THz radiation</li> <li>• Gated detection, Austin switches</li> </ul> Elementary excitations in solid materials <ul style="list-style-type: none"> <li>• Rotational-vibrational bands</li> <li>• Infrared-active phonons</li> <li>• Interband excitations</li> <li>• Crystal-field excitations</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic principles of far-infrared spectroscopy and terahertz time-domain-spectroscopy,</li> <li>• The students know about fundamental optical excitations in condensed matter materials that can be studied by these spectroscopic methods,</li> <li>• The students obtain the competence to plan and carry out complex experiments,</li> <li>• The students have the skills to evaluate and analyze optical data.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Remarks:</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 90 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge in solid-state physics, basic knowledge in electrodynamics and optics		<b>Credit Requirements:</b> written report
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module**

**Part of the Module: Method Course: Optical Properties of Solids**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 2

**Literature:**

Mark Fox, Optical Properties of Solids, Oxford Master Series

Eugene Hecht, Optics, Walter de Gruyter

**Part of the Module: Method Course: Optical Properties of Solids (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Examination**

**Method Course: Optical Properties of Solids**

report, graded

**Examination Prerequisites:**

Method Course: Optical Properties of Solids

<b>Module PHM-0149: Method Course: Methods in Biophysics</b> <i>Method Course: Methods in Biophysics</i>		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Dr. Christoph Westerhausen		
<b>Contents:</b> Unit Membrane biophysics <ul style="list-style-type: none"> <li>• Preparation of synthetic lipid membranes</li> <li>• Size, fluorescence and phase transition characterization of lipid membranes</li> <li>• Nanoparticle uptake synthetic membrane</li> </ul> Unit microfluidic <ul style="list-style-type: none"> <li>• Microfluidic systems</li> <li>• Fabrication of microfluidic systems</li> <li>• Calculation of microfluidic problems</li> </ul> Unit live cell experiments <ul style="list-style-type: none"> <li>• Cell culture</li> <li>• Cell counting and separation using microfluidics</li> </ul> Unit analysis		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know basic terms, concepts and phenomena in biophysics</li> <li>• acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic manipulation and analysis systems,</li> <li>• learn skills in tissue culture and immun-histochemical staining procedures,</li> <li>• learn skills in fluorescence microscopy,</li> <li>• learn skills to calculate fluidic problems on small length scales,</li> <li>• learn skills to handle microfluidic channel systems.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Attendance of the lecture "Biophysics and Biomaterials"		<b>Credit Requirements:</b> 1 written lab report
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Methods in Biophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

**Part of the Module: Method Course: Methods in Biophysics (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Literature:**

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle und R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- Lecture notes

**Examination**

**Method Course: Methods in Biophysics**

report, graded

**Examination Prerequisites:**

Method Course: Methods in Biophysics

<b>Module PHM-0151: Method Course: Porous Materials - Synthesis and Characterization</b> <i>Method Course: Porous Materials - Synthesis and Characterization</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15 to WS21/22) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> Synthesis of porous functional materials (e.g. aerogels, mesoporous silica materials, zeolites, Metal-Organic Frameworks) Characterization methods <ul style="list-style-type: none"> <li>• Structure and composition (XRD, UV/VIS, IR, ESEM, EDX)</li> <li>• Thermal analysis (TGA)</li> <li>• Adsorption and diffusion (BET, pore size distribution, pulse chemisorption)</li> <li>• Catalytic properties (GC/MS, TPO, TPR)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students will learn how to <ul style="list-style-type: none"> <li>• use modern solid state preparation techniques (e.g. hydrothermal, solvothermal, microwave synthesis),</li> <li>• employ analytical methods dedicated to porous materials.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 120 h internship / practical course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: lecture Functional Porous Materials		<b>Credit Requirements:</b> written report (editing time 3 weeks) + written exam  Please note that final grade of the Method Course consists of the maximum point score of the exam and the grade of the report of the practical part which are weighted (40:60).
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Porous Materials Synthesis and Characterization (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4		

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**Examination**

**Method Course: Porous Materials Synthesis and Characterization**

written exam / length of examination: 45 minutes, graded

**Examination Prerequisites:**

Method Course: Porous Materials Synthesis and Characterization

<b>Module PHM-0153: Method Course: Magnetic and Superconducting Materials</b> <i>Method Course: Magnetic and Superconducting Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> Methods of growth and characterization: Sample preparation (bulk materials and thin films), e.g., <ul style="list-style-type: none"> <li>• arc melting</li> <li>• flux-growth</li> <li>• sputtering and evaporation</li> </ul> Sample characterization, e.g., <ul style="list-style-type: none"> <li>• X-ray diffraction</li> <li>• electron microscopy, scanning tunneling microscopy</li> <li>• magnetic susceptibility, electrical resistivity</li> <li>• specific heat</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• get to know the basic methods of materials growth and characterization, such as poly- and single crystal growth, thin-film growth, X-ray diffraction, magnetic susceptibility, dc-conductivity, and specific heat measurements</li> <li>• are trained in planning and performing complex experiments</li> <li>• learn to evaluate and analyze the collected data, are taught to work on problems in experimental solid state physics, including analysis of measurement results and their interpretation in the framework of models and theories</li> </ul>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics and quantum mechanics		<b>Credit Requirements:</b> presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Magnetic and Superconducting Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

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**Part of the Module: Method Course: Magnetic and Superconducting Materials (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Examination**

**Method Course: Magnetic and Superconducting Materials**

report, graded

**Examination Prerequisites:**

Method Course: Magnetic and Superconducting Materials



<b>Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy</b> <i>Method Course: Modern Solid State NMR Spectroscopy</i>		8 ECTS/LP
Version 2.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
<b>Contents:</b> Physical foundations of NMR spectroscopy Internal interactions in NMR spectroscopy <ul style="list-style-type: none"> <li>• Chemical shift interaction</li> <li>• Dipole interaction and</li> <li>• Quadrupolar interaction</li> </ul> Magic Angle Spinning techniques Modern applications of NMR in materials science Experimental work at the Solid-State NMR spectrometers, computer-aided analysis and interpretation of acquired data		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• gain basic knowledge of the physical foundations of modern Solid-State NMR spectroscopy,</li> <li>• gain basic practical knowledge of operating a solid-state NMR spectrometer,</li> <li>• can -- under guidance -- plan, perform, and analyze modern solid-state NMR experiments for the structural characterization of advanced materials.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
<b>Conditions:</b> The attendance of the lecture "NOVEL METHODS IN SOLID STATE NMR SPECTROSCOPY" is highly recommended.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Modern Solid State NMR Spectroscopy</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 2		

**Literature:**

- M. H. Levitt, spin Dynamics, John Wiley and Sons, Ltd., 2008.
- H. Günther NMR spectroscopy, Wiley, 2001.
- M. Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
- D. Canet, NMR - concepts and methods, Springer, 1994.

**Part of the Module: Method Course: Modern Solid State NMR Spectroscopy (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Literature:**

1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008.
2. H. Günther, NMR spectroscopy, Wiley 2001.
3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
4. D. Canet: NMR - concepts and methods, Springer, 1994.

**Examination**

**Method Course: Modern Solid State NMR Spectroscopy**

report / work period for assignment: 2 weeks, graded

**Examination Prerequisites:**

Method Course: Modern Solid State NMR Spectroscopy

<b>Module PHM-0171: Method Course: Coordination Materials</b> <i>Method Course: Coordination Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer Dr. Hana Bunzen		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Synthesis of metal complexes:</li> <li>2. Analytical characterization of metal complexes (thermal analysis, UV/vis spectroscopy, IR spectroscopy, X-ray diffraction)</li> <li>3. Material composition and stability studies</li> <li>4. Functional coordination materials (spin-crossover materials, oxygen-carrying materials)</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students will learn how to: <ul style="list-style-type: none"> <li>• prepare transition metal complexes employing modern preparation techniques (e.g. microwave synthesis), inert synthesis conditions (Schlenk technique),</li> <li>• characterize coordination compounds by selected analytical techniques,</li> <li>• develop functional coordination materials based on organic / inorganic hybrid compounds,</li> <li>• employ X-ray diffraction methods for structural analysis.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 120 h lecture and exercise course (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> written report (protocols)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Coordination Materials (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Part of the Module: Method Course: Coordination Materials (Seminar)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Chemical databases</li> <li>• Primary literature</li> </ul>		

**Examination**

**Method Course: Coordination Materials (Seminar)**

seminar, graded

**Examination Prerequisites:**

Method Course: Coordination Materials (Seminar)

<b>Module PHM-0172: Method Course: Functional Silicate-analogous Materials</b> <i>Method Course: Functional Silicate-analogous Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> Synthesis and characterization of functional materials according to the topics: <ol style="list-style-type: none"> <li>1. Silicate-analogous compounds</li> <li>2. Luminescent materials / phosphors</li> <li>3. Pigments</li> <li>4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students will know how to: <ul style="list-style-type: none"> <li>• develop functional materials based on silicate-analogous materials,</li> <li>• apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),</li> <li>• work under non-ambient atmospheres (e.g. reducing, inert conditions),</li> <li>• solve and refine crystal structures from single-crystal data,</li> <li>• describe and classify these structures properly.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 120 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: attendance to the lecture "Advanced Solid State Materials"		<b>Credit Requirements:</b> written report (protocol)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 6		

**Learning Outcome:**

The students will know how to:

- develop functional materials based on silicate-analogous materials,
- apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),
- work under non-ambient atmospheres (e.g. reducing, inert conditions),
- solve and refine crystal structures from single-crystal data,
- describe and classify these structures properly.

**Contents:**

Synthesis and characterization of functional materials according to the topics:

1. Silicate-analogous compounds
2. Luminescent materials / phosphors
3. Pigments
4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis

**Examination**

**Method Course: Functional Silicate-analogous Materials**

seminar, graded

**Examination Prerequisites:**

Method Course: Functional Silicate-analogous Materials

<b>Module PHM-0206: Method Course: Infrared Microspectroscopy under Pressure</b> <i>Method Course: Infrared Microspectroscopy under Pressure</i>		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Christine Kuntscher		
<p><b>Contents:</b></p> <p>Electrodynamics of solids</p> <p>Maxwell equations and electromagnetic waves in matter</p> <p>Optical variables</p> <p>Theories for dielectric function:</p> <p>i. Free carriers in metals and semiconductors (Drude)</p> <p>ii. Interband absorptions in semiconductors and insulators</p> <p>iii. Vibrational absorptions</p> <p>iv. Multilayer systems</p> <p>FTIR microspectroscopy</p> <p>Components of FTIR spectrometers</p> <p>i. Light sources</p> <p>ii. Interferometers</p> <p>iii. Detectors</p> <p>Microscope components</p> <p>High pressure experiments Equipments</p> <p>Pressure calibration</p> <p>Experimental techniques under high pressure</p> <p>i. IR spectroscopy</p> <p>ii. Raman scattering</p> <p>iii. Magnetic measurements</p> <p>iv. Transport measurements</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students</p> <p>Learn about the basics of the light interaction with various materials and the fundamentals of FTIR microspectroscopy,</p> <p>Are introduced to the high pressure equipments used in infrared spectroscopy,</p> <p>Learn to carry out infrared microspectroscopy experiments under pressure,</p> <p>Learn to analyze the measured optical spectra.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Written report
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Infrared Microspectroscopy under Pressure</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Assigned Courses:</b> <b>Method Course: Infrared Microspectroscopy under Pressure</b> (lecture)
<b>Part of the Module: Method Course: Infrared Microspectroscopy under Pressure (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Method Course: Infrared Microspectroscopy under Pressure (Practical Course)</b> (internship)
<b>Examination</b> <b>Method Course: Infrared Microspectroscopy under Pressure</b> report, graded



<b>Module PHM-0216: Method Course: Thermal Analysis</b> <i>Method Course: Thermal Analysis</i>		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Ferdinand Haider Dr. Robert Horny		
<b>Contents:</b> Methods of thermal analysis: - Differential Scanning Calorimetry: DSC, DTA - Thermo-gravimetric Analysis: TGA - Dilatometry: DIL - Dynamic-mechanical Analysis: DMA -Rheology: RHEO  Advanced Methods: - Modulated Differential Scanning Calorimetry: MDSC - Evolved Gas Analysis: EGA (GCMS, FTIR)		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• get to know the basic principles of thermal analysis</li> <li>• learn about fundamental thermal processes in condensed matter ,e.g. phase transitions and relaxation processes (metals, polymers, ceramics)</li> <li>• learn to plan and carry out complex experiments and the usage of advanced measurement techniques</li> <li>• learn how to evaluate and analyze thermal data</li> <li>• are aware of common raw data artefacts leading to misinterpretation</li> </ul>		
<b>Remarks:</b>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 30 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in solid-state physics		<b>Credit Requirements:</b> regular participation, oral presentation (10 min), written report
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Thermal Analysis</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Ferdinand Haider <b>Language:</b> English <b>Contact Hours:</b> 2		

**Literature:**

- Differential scanning calorimetry, Höhne, Hemminger, Flammersheim, H., Springer, 2003
- Practical Gas Chromatography, Dettmer-Wilde, Engewald, Springer, 2014
- Das Rheologie-Handbuch, Mezger, Vincentz, 2010

**Assigned Courses:**

**Method Course: Thermal Analysis** (course)

**Part of the Module: Method Course: Thermal Analysis (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Assigned Courses:**

**Method Course: Thermal Analysis** (course)

**Examination**

**Method Course: Thermal Analysis**

report, graded

<b>Module PHM-0221: Method Course: X-ray Diffraction Techniques</b> <i>Method Course: X-ray Diffraction Techniques</i>		8 ECTS/LP
Version 1.4.0 (since WS15/16 to SoSe23) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<p><b>Contents:</b></p> <p>Subjects of the practical training and the accompanying lecture are the theoretical basics and the practical application of X-ray diffraction techniques:</p> <p>Data collection and reduction techniques</p> <p>Symmetry and space group determination</p> <p>Structural refinements:</p> <ul style="list-style-type: none"> <li>• The Rietveld method</li> <li>• Difference Fourier synthesis</li> </ul> <p>Structure determination:</p> <ul style="list-style-type: none"> <li>• Patterson method</li> <li>• Direct methods</li> </ul> <p>Interpretation of structural refinement results</p> <p>Errors and Pitfalls: twinning and disorder</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students:</p> <ul style="list-style-type: none"> <li>• gain basic practical knowledge on structural characterization methods for single- and poly-crystalline samples employing X-ray diffraction techniques,</li> <li>• have the skill to perform under guidance phase-analyses and X-ray structure determinations</li> <li>• are competent to analyze hands-on the structure-property relationships of new materials</li> </ul>		
<p><b>Remarks:</b></p> <p><b>ELECTIVE COMPULSORY MODULE</b></p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>90 h lecture and exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module**

**Part of the Module: Method Course: X-ray Diffraction Techniques**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 2

**Literature:**

1. C. Giacovazzo et al., Fundamentals of Crystallography, Oxford Univ. Press, 2011.
2. W. Massa, Crystal structure determination, Berlin, Springer, 2016.

**Part of the Module: Method Course: X-ray Diffraction Techniques (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** German

**Contact Hours:** 4

**Examination**

**Method Course: X-ray Diffraction Techniques**

written exam / length of examination: 90 minutes, graded

<b>Module PHM-0234: 2D Materials</b> <i>2D Materials</i>		6 ECTS/LP
Version 1.0.1 (since SoSe18 to WS21/22) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<b>Contents:</b> Two-dimensional materials: graphene to emerging new materials, such as transition metal dichalcogenides <ol style="list-style-type: none"> <li>1. Fabrication</li> <li>2. Optical, electronic and vibrational properties</li> <li>3. Applications in advanced functional devices</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ol style="list-style-type: none"> <li>1. Specify different classes of 2D solid state materials and their properties.</li> <li>2. Describe and explain preparation and nanofabrication methods for 2D materials.</li> <li>3. Understand and explain and differentiate between suitable optical and structural characterization methods for 2D materials.</li> <li>4. Understand and explain phonon properties of 2D materials.</li> <li>5. Understand and explain magneto quantum transport phenomena such as the quantum Hall effect in graphene</li> <li>6. Understand and explain absorption, excitonic and spin properties of transition metal dichalcogenides..</li> <li>7. Understand and explain and discuss applications of 2D materials and their heterostructures for electronic, optoelectronic, spintronics devices and solar energy conversion.</li> </ol>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 60 h lecture (attendance) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: 2D Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4 <b>ECTS Credits:</b> 6.0		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Examination**

**2D Materials**

oral exam / length of examination: 30 minutes, graded

**Examination Prerequisites:**

2D Materials

<b>Module PHM-0235: Method Course: 2D Materials</b> <i>Method Course: 2D Materials</i>		8 ECTS/LP
Version 1.0.1 (since SoSe18 to WS21/22) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<b>Contents:</b> 1. Fabrication of monolayers of 2D Materials on different substrates 2. Characterization of the structural, optical and vibrational properties of 2D Materials 3. Modelling of selected physical properties of these materials		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Knowledge and practical application of fabrication of selected monolayer 2D Materials</li> <li>• Knowledge and practical application of basic characterization methods for these materials</li> <li>• Practical application of simulation methods</li> <li>• Planning and conducting experiments</li> <li>• Data analysis</li> </ul>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Basic knowledge of solid state physics, optics and quantum mechanics		<b>Credit Requirements:</b> written report, editing time 3 weeks, max. 30 pages
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: 2D Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Part of the Module: Method Course: 2D Materials (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4		

<b>Examination</b> <b>Method Course: 2D Materials</b> report, graded <b>Description:</b> written report
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<b>Module PHM-0228: Symmetry concepts and their applications in solid state physics and materials science</b> <i>Symmetry concepts and their applications in solid state physics and materials science</i>	6 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. István Kézsmárki Deisenhofer, Joachim, Dr.	
<p><b>Contents:</b></p> <p>The topical outline of the course is as follows:</p> <ul style="list-style-type: none"> <li>• Introduction and common examples <ul style="list-style-type: none"> <li>o Motivating examples</li> <li>o Polar and axial vectors and tensors</li> <li>o Spatial and temporal symmetries and charge conjugation</li> <li>o Symmetries of measurable quantities and fields</li> <li>o Symmetries of physical laws (classical and quantum)</li> <li>o Conservation laws (linear and angular momentum, energy, etc.)</li> <li>o Symmetry of measurement configurations (reciprocity, etc.)</li> </ul> </li> <li>• Neumann principle <ul style="list-style-type: none"> <li>o Linear response theory and Onsager relations</li> <li>o Applications to vector and tensor quantities: electric and magnetic dipole moment of molecules; ferroelectricity, ferromagnetism, piezoelectricity and magnetoelectricity in crystals; wave propagation in anisotropic media (sound and light)</li> </ul> </li> <li>• Symmetry allowed energy terms <ul style="list-style-type: none"> <li>o On the level of classical free energy: Polar, nematic and magnetic order parameters (Landau expansion)</li> <li>o On the level of Hamiltonians: Molecular vibrations, crystal field potential, magnetic interactions</li> </ul> </li> <li>• Symmetry of physical states <ul style="list-style-type: none"> <li>o Spatial inversion and parity eigenstates</li> <li>o Discrete translations and the Bloch states</li> </ul> </li> <li>• Spontaneous symmetry breaking upon phase transitions (Landau theory)</li> <li>• Outlook: Symmetry guides for skyrmion-host materials, multiferroic compounds and axion insulators</li> </ul>	
<p><b>Learning Outcomes / Competences:</b></p> <ul style="list-style-type: none"> <li>• The students know the simple use of symmetry concepts to understand phenomena and material properties without performing detailed calculations.</li> <li>• The students know how to make minimal plans for experiments using the symmetry of the studied materials or vice versa how to determine the symmetry of materials from the output of experiments.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>	
<p><b>Workload:</b></p> Total: 180 h 60 h (attendance) 60 h exam preparation (self-study) 60 h studying of course content (self-study)	



<b>Conditions:</b> Background in basic quantum mechanics is required.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module:</b> Symmetry concepts and their applications in solid state physics and materials science</p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Lecturers:</b> Prof. Dr. István Kézsmárki</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 3</p> <p><b>ECTS Credits:</b> 6.0</p>
<p><b>Examination</b></p> <p><b>Symmetry concepts and their applications in solid state physics and materials science</b></p> <p>oral exam / length of examination: 30 minutes, graded</p>

<b>Parts of the Module</b>
<p><b>Part of the Module:</b> Symmetry concepts and their applications in solid state physics and materials science (Tutorial)</p> <p><b>Mode of Instruction:</b> exercise course</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 1</p>

<b>Module PHM-0223: Method Course: Tools for Scientific Computing</b> <i>Method Course: Tools for Scientific Computing</i>	8 ECTS/LP
Version 1.6.0 (since SoSe18) Person responsible for module: Prof. Dr. Gert-Ludwig Ingold	
<b>Contents:</b> Important tools for scientific computing are taught in this module and applied to specific scientific problems by the students. As far as tools depend on a particular programming language, Python will be employed. Tools to be discussed include: <ul style="list-style-type: none"> <li>• numerical libraries like NumPy and SciPy</li> <li>• visualisation of numerical results</li> <li>• use of a version control system like git and its application in collaborative work</li> <li>• testing of code</li> <li>• profiling</li> <li>• documentation of programs</li> </ul>	
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are capable of solving a physical problem of some complexity by means of numerical techniques. They are able to visualize the results and to adequately document their program code.</li> <li>• The students know examples of numerical libraries and are able to apply them to solve scientific problems.</li> <li>• The students know methods for quality assurance like the use of unit tests and can apply them to their code. They know techniques to identify run-time problems.</li> <li>• The students know a distributed version control system and are able to use it in a practical problem.</li> <li>• The students have gained practical experience in a collaborative project work. They are able to plan and carry out a programming project in a small group.</li> <li>• The students understand the relevance of the tools taught in the method course for good scientific practice.</li> </ul>	
<b>Remarks:</b> The number of students will be limited to 12.	
<b>Workload:</b> Total: 240 h 60 h studying of course content (self-study) 90 h (attendance) 30 h preparation of presentations (self-study) 60 h preparation of written term papers (self-study)	
<b>Conditions:</b> Knowledge of the programming language Python is expected on the level taught in the module PHM-0243 "Einführung in Prinzipien der Programmierung".	<b>Credit Requirements:</b> The module examination needs to be passed which is based on a scientific programming project carried out in a small team of 2-3 students. The work will be judged on the basis of a joint final report and the contributions of the individual students as documented in the team's Gitlab project. The final report should contain an explanation of the scientific problem and its numerical implementation as well as a presentation of results. The code should be appropriately documented and tested.

<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Method Course: Tools for Scientific Computing****Mode of Instruction:** lecture**Language:** English / German**Contact Hours:** 2**Learning Outcome:**

- The students know the numerical libraries NumPy and SciPy and selected tools for the visualization of numerical results.
- The students know fundamental techniques for the quality assurance of programs like the use of unit tests, profiling and the use of the version control system git. They are able to adequately document their code.
- The students understand the relevance of the tools taught in the method course for good scientific practice.

**Contents:**

- numerical libraries NumPy and SciPy
- graphics with matplotlib
- version control system Git and workflow for Gitlab/Github
- unit tests
- profiling
- documentation using docstrings and Sphinx

**Literature:**

- A. Scopatz, K. D. Huff, *Effective Computation in Physics* (O'Reilly, 2015)
- lecture notes are freely available at <https://gertingold.github.io/tools4scicomp>

**Part of the Module: Method Course: Tools for Scientific Computing (Practical Course)****Mode of Instruction:** internship**Language:** English / German**Contact Hours:** 4**Learning Outcome:**

- The students are capable of solving a physical problem of some complexity by means of numerical techniques and to visualize the results.
- They have gained some experience in the application of methods for quality assurance of their code and are able to appropriately document their programs.
- The students are able to work in a team and know how to make use of tools like Gitlab/Github.
- The students are able to present the status of their work, to critically assess it and to accept suggestions from others.

**Contents:**

The tools discussed in the lecture will be applied to specific scientific problems by small teams of 2-3 students under supervision. The teams regularly inform the other teams in oral presentations on their progress, the tools employed as well as encountered problems and their solution.

**Examination**

**Method Course: Tools for Scientific Computing**

report / work period for assignment: 4 weeks, graded

**Test Frequency:**

when a course is offered

**Description:**

The requirement for credit points is based on a scientific programming project carried out in a small team of 2-3 students. The work will be judged on the basis of a joint final report and the contributions of the individual students as documented in the team's Gitlab project. The final report should contain an explanation of the scientific problem and its numerical implementation as well as a presentation of results. The code should be appropriately documented and tested.

<b>Module PHM-0224: Method Course: Theoretical Concepts and Simulation</b> <i>Method Course: Theoretical Concepts and Simulation</i>		8 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Liviu Chioncel		
<b>Contents:</b> This module covers Monte-Carlo methods (computational algorithms) for classical and quantum problems. Python as programming language will be employed. The following common applications will be discussed: <ul style="list-style-type: none"> <li>• Monte-Carlo integration, stochastic optimization, inverse problems</li> <li>• Feynman path integrals: the connection between classical and quantum systems</li> <li>• Order and disorder in spin systems, fermions, and boson</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are capable of obtaining numerical solutions to problems too complicated to be solved analytically</li> <li>• The students are able to present (graphically), discuss and analyze the results</li> <li>• The students gain experience in formulating and carrying out a collaborative project</li> </ul>		
<b>Remarks:</b> The number of students will be limited to 8.		
<b>Workload:</b> Total: 240 h 90 h preparation of presentations (self-study) 60 h preparation of written term papers (self-study) 60 h studying of course content (self-study) 90 h (attendance)		
<b>Conditions:</b> Knowledge of the programming language Python is expected on the level taught in the modul PHM-0041. Requirements to understand basic concepts in physics: Classical Mechanics (Newton, Lagrange), Electrodynamics, Thermodynamics and Quantum Mechanics.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Theoretical Concepts and Simulation</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2
<b>Contents:</b> Concepts of classical and quantum statistical physics: <ul style="list-style-type: none"> <li>• the meaning of sampling, random variables, ergodicity</li> <li>• equidistribution, pressure, temperature</li> <li>• path integrals, quantum statistics, enumeration, cluster algorithms</li> </ul>
<b>Literature:</b> <ol style="list-style-type: none"> <li>1. Werner Krauth, Algorithms and Computations (Oxford University Press, 2006)</li> <li>2. R. H. Landau, A Survey of Computational Physics (Princeton Univ. Press, 2010)</li> </ol>

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**Part of the Module: Method Course: Theoretical Concepts and Simulation (Practical Course)**

**Mode of Instruction:** internship

**Language:** English / German

**Contact Hours:** 4

**Contents:**

see above

**Literature:**

see above

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**Examination**

**Method Course: Theoretical Concepts and Simulation**

report / work period for assignment: 4 weeks, graded

**Description:**

The requirement for the credit points is based on a programming project carried out in a team of 2-3 students. The final report contains the formulation and a theoretical introduction into the problem, the numerical implementation, and the presentation of the results.

<b>Module PHM-0225: Analog Electronics for Physicists and Materials Scientists</b> <i>Analog Electronics for Physicists and Materials Scientists</i>		6 ECTS/LP
Version 1.2.0 (since WS15/16) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering</li> <li>2. Quadrupole theory</li> <li>3. Electronic Networks</li> <li>4. Semiconductor Devices</li> <li>5. Implementation of transistors</li> <li>6. Operational amplifiers</li> <li>7. Optoelectronic Devices</li> <li>8. Measurement Devices</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the Lab,</li> <li>• have skills in easy circuit design, measuring and control technology, analog electronics,</li> <li>• have expertise in independent working on circuit problems. They can calculate and develop easy circuits.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Analog Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture + exercise <b>Lecturers:</b> Andreas Hörner <b>Language:</b> English <b>Contact Hours:</b> 4 <b>ECTS Credits:</b> 6.0		
<b>Assigned Courses:</b> <b>Analog Electronics for Physicists and Materials Scientists</b> (lecture)		

**Examination**

**Analog Electronics Analog Electronics for Physicists and Materials Scientists**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

only in the winter semester

**Examination Prerequisites:**

Analog Electronics for Physicists and Materials Scientists



<b>Module PHM-0226: Digital Electronics for Physicists and Materials Scientists</b> <i>Digital Electronics for Physicists and Materials Scientists</i>		6 ECTS/LP
Version 1.3.0 (since WS15/16) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Boolean algebra and logic gates</li> <li>2. Digital electronics and calculation of digital circuits</li> <li>3. Converters (Analog – Digital, Digital – Analog)</li> <li>4. Principle of digital memory and communication,</li> <li>5. Microprocessors and Networks</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the Lab,</li> <li>• have skills in easy circuit design, measuring and control technology and digital electronics,</li> <li>• have expertise in independent working on circuit problems. They develop easy digital circuits and program microprocessors</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Digital Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture + exercise <b>Lecturers:</b> Andreas Hörner <b>Language:</b> English <b>Contact Hours:</b> 4 <b>ECTS Credits:</b> 6.0		
<b>Examination</b> <b>Digital Electronics Digital Electronics for Physicists and Materials Scientists</b> written exam / length of examination: 90 minutes, graded <b>Test Frequency:</b> only in the summer semester		

<b>Module PHM-0150: Method Course: Spectroscopy on Condensed Matter</b> <i>Method Course: Spectroscopy on Condensed Matter</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. István Kézsmárki		
<b>Contents:</b> Dielectric Spectroscopy [8] <ul style="list-style-type: none"> <li>• Methods</li> <li>• Cryo-techniques</li> <li>• Measurement quantities</li> <li>• Relaxation processes</li> <li>• Dielectric phenomena</li> </ul> Ferroelectric Materials [7] <ul style="list-style-type: none"> <li>• Mechanism of ferroelectric polarization</li> <li>• Hysteresis loop measurements</li> <li>• Dielectric spectroscopy</li> </ul> Glassy Matter [8] <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Glassy phenomena</li> <li>• Dielectric spectroscopy</li> </ul> Multiferroic Materials [7] <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Microscopic origins of multiferroicity</li> <li>• Pyrocurrent measurements</li> <li>• Dielectric spectroscopy</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• learn about the basic concepts of dielectric spectroscopy and the phenomena examined with it. Therefore they are instructed in experimental methods for the investigation of the dielectric properties of condensed matter,</li> <li>• are trained in planning and performing complex experiments. They learn to evaluate and analyze the collected data,</li> <li>• are taught to work on problems in experimental solid state physics, including analysis of measurement results and their interpretation in the framework of models and theories.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics, basic knowledge in physics of glasses and supercooled liquids		<b>Credit Requirements:</b> written report on the experiments (editing time 2 weeks)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module**

**Part of the Module: Method Course: Spectroscopy on Condensed Matter**

**Mode of Instruction:** lecture

**Language:** English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2

**Literature:**

- N.W. Ashcroft, N.D. Mermin, Festkörperphysik (Oldenbourg)
- Ch. Kittel, Einführung in die Festkörperphysik (Oldenbourg)
- C.J.F. Böttcher, P. Bordewijk, Theory of Electric Polarization (Elsevier)
- J. R. Macdonald, Impedance Spectroscopy (Wiley)
- H. Scholze, Glas (Springer)
- S.R. Elliott, Physics of Amorphous Materials (Longman)
- R. Zallen, The Physics of Amorphous Solids (Wiley)

**Part of the Module: Method Course: Spectroscopy on Condensed Matter (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 4

**Examination**

**Method Course: Spectroscopy on Condensed Matter**

oral exam / length of examination: 45 minutes, graded

**Examination Prerequisites:**

Method Course: Spectroscopy on Condensed Matter

<b>Module PHM-0169: Masterthesis</b> <i>Masterthesis</i>		26 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> According to chosen topic		
<b>Remarks:</b> The master's thesis will be offered in SoSe 2020 as soon as the current situation allows.		
<b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 780 h 260 h studying of course content using provided materials (self-study) 520 h lecture and exercise course (attendance)		
<b>Conditions:</b> To begin with the Masterthesis students must have acquired 72 CP from modules consisting of the modulgroups 1a - 5.  Recommended: according to the respective advisor		<b>Credit Requirements:</b> written thesis
<b>Frequency:</b> each semester Siehe Bemerkungen	<b>Recommended Semester:</b> from 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Masterthesis****Language:** English**Learning Outcome:**  
see description of module**Contents:**  
see description of module**Examination****Masterthesis**

Master's thesis, graded

**Examination Prerequisites:**

Masterthesis

<b>Module PHM-0170: Colloquium</b> <i>Colloquium</i>		4 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> According to the respective Masterthesis		
<b>Remarks:</b> The Colloquium will be offered in SoSe 2020 as soon as the current situation allows.		
<b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 120 h 40 h studying of course content using provided materials (self-study) 80 h lecture and exercise course (attendance)		
<b>Conditions:</b> submission of the masterthesis		
<b>Frequency:</b> each semester Siehe Bemerkungen	<b>Recommended Semester:</b> from 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Colloquium</b> <b>Language:</b> English
<b>Learning Outcome:</b> see description of module
<b>Contents:</b> see description of module
<b>Assigned Courses:</b> <b>Masterarbeits-Seminar</b> (seminar)

<b>Examination</b> <b>Colloquium</b> seminar / length of examination: 20 minutes, graded <b>Examination Prerequisites:</b> Colloquium
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