Handbook of Modules

Master Advanced Functional Materials (FAME)

Faculty of Mathematics, Natural Sciences, and Materials Engineering

valid from Winter Semester 2015/2016

Prüfungsordnung vom 26.02.2014

Index by Groups of Modules

Module PHM-0144: Materials Physics		ECTS Credits: 6
Version 1.1.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: • Electrons in solids • Phonons • Properties of metals, semiconductors and insulators • Application in optical, electronic, and optoelectronic devices • Dielectric solids, optical properties		
Learning Outcomes / Competences: • 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, • are capable to apply derived approximations as the effective mass or the electron-hole concept to describe basic characteristics of semiconductor materials, • have the competence to apply these concepts for the description of electric, electro-optic and thermal properties of solids and to describe their functionalities, • understand size effects on material physical properties. • Integrated acquirement of soft skills: Working with specialist literature, literature search and interdisciplinary thinking.		
Remarks: compulsory module		
Workload: Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: basic knowledge of solid state physics		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Materials Physics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: 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)

2. 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

Module PHM-0110: Materials Chemistry		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Henning Höppe		

Contents:
• Revision of basic chemical concepts
• Solid state chemical aspects of selected materials, such as
    o Thermoelectrics
    o Battery electrode materials, ionic conductors
    o Hydrogen storage materials
    o Data storage materials
    o Phosphors and pigments
    o Ferroelectrics and Piezoelectrics
    o Heterogeneous catalysis
    o nanoscale materials		

Learning Outcomes / Competences: The students will • be able to apply basic chemical concepts on materials science problems, • 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, • be able to assess synthetic approaches towards relevant materials, • acquire skills to perform literature research using online data bases.		
Workload: Total: 180 h 20 h studying of course content using literarture (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)		
Conditions: The lecture course is based on the Bachelor in Materials Science courses Chemie I and Chemie III (solid state chemistry).		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Materials Chemistry **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see description of module
Contents: 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.

Assigned Courses:

Materials Chemistry (lecture)

2. 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

Assigned Courses:

Materials Chemistry (Tutorial) (exercise course)

Examination

Materials Chemistry

written exam / length of examination: 90 minutes

Module PHM-0117: Surfaces and Interfaces		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Siegfried Horn		

Contents:

Introduction

- The importance of surfaces and interfaces

Some basic facts from solid state physics

- Crystal lattice and reciprocal lattice
- Electronic structure of solids
- Lattice dynamics

Physics at surfaces and interfaces

- Structure of ideal and real surfaces
- Relaxation and reconstruction
- Transport (diffusion, electronic) on interfaces
- Thermodynamics of interfaces
- Electronic structure of surfaces
- Chemical reactions on solid state surfaces (catalysis)
- Interface dominated materials (nano scale materials)

Methods to study chemical composition and electronic structure, application examples

- Scanning electron microscopy
- Scanning tunneling and scanning force microscopy
- Auger – electron – spectroscopy
- Photo electron spectroscopy

Learning Outcomes / Competences:

The students:

- have knowledge of the structure, the electronical properties, the thermodynamics, and the chemical reactions on surfaces and interfaces,
- acquire the skill to solve problems of fundamental research and applied sciences in the field of surface and interface physics,
- have the competence to solve certain problems autonomously based on the thought physical basics.
- Integrated acquirement of soft skills.

Workload:

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 literarture (self-study)

80 h studying of course content through exercises / case studies (self-study)

Conditions: The module "Physics IV - Solid State Physics" of the Bachelor of Physics / Materials Science program should be completed first.		
Frequency: each winter semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Surfaces and Interfaces

Mode of Instruction: lecture
Language: English
Frequency: annually
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Ertl, Küppers: Low Energy Electrons and Surface Chemistry (VCH)
- Lüth: Surfaces and Interfaces of Solids (Springer)
- Zangwill: Physics at Surfaces (Cambridge)
- Feldmann, Mayer: Fundamentals of Surface and thin Film Analysis (North Holland)
- Henzler, Göpel: Oberflächenphysik des Festkörpers (Teubner)
- Briggs, Seah: Practical Surface Analysis I und II (Wiley)

Assigned Courses:

Surfaces and Interfaces (lecture)

2. Part of the Module: Surfaces and Interfaces (Tutorial)

Mode of Instruction: exercise course
Language: English
Frequency: annually
Contact Hours: 1

Assigned Courses:

Surfaces and Interfaces (lecture)

Examination

Surfaces and Interfaces
written exam / length of examination: 90 minutes

Module PHM-0053: Chemical Physics I		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer		
Contents: • Basics of quantum chemical methods • Molecular symmetry and group theory • The electronical structure of transition metal complexes		
Learning Outcomes / Competences: The students: • know the basics of the extended-Hückel-method and the density functional theory, • know the basics of group theory, • are able to apply the knowledge gained through consideration of symmetry from vibration-, NMR-, and UV/VIS-spectroscopy, and • are able to interpret and predict the basical geometric, electronical and magnetical properties of transition metal complexes. • Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.		
Remarks: It is possible for students to do EHM calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.		
Workload: Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: It is recommended to complete the experiments FP11 (IR-spectroscopy) and FP17 (Raman-spectroscopy) of the module "Physikalisches Fortgeschrittenenpraktikum".		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Chemical Physics I **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Basics of quantum chemical methods
  - Extended Hueckel method (EHM)
  - Modern quantum chemical methods of chemical physics
  - Application: exemplary calculations and interpretation of simple electronical structures
- Molecular symmetry and group theory
  - Symmetry operations and matrix transformations
  - Point groups
  - Reducible and irreducible representations
  - Character tables
  - Application: infrared- and raman-spectroscopy, NMR-spectroscopy
- The electronical structure of transition metal complexes
  - Ligand field theory and angular-overlap model (AOM)
  - The physical basics of the spectrochemical series
  - Molecular orbital theory of transition metal complexes
  - Application: UV/VIS-spectroscopy, molecular magnetism

Literature:

- J. Reinhold, Quantentheorie der Moleküle (Teubner)
- H.-H. Schmidtke, Quantenchemie (VCH)
- D. C. Harris und M. D. Bertolucci, Symmetry and Spectroscopy (Dover Publications)
- D. M. Bishop, Group Theory and Chemistry (Dover Publications)
- J. K. Burdett, Chemical Bonds: A Dialog (Wiley)
- F. A. Kettle, Physical Inorganic Chemistry (Oxford University Press)
- A. Frisch, Exploring Chemistry with Electronic Structure Methods (Gaussian Inc. Pittsburg, PA)

Assigned Courses:

Chemical Physics I (lecture)

2. Part of the Module: Chemical Physics I (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Chemical Physics I (Tutorial) (exercise course)

Examination

Chemical Physics I

written exam / length of examination: 90 minutes

Module PHM-0171: Method Course: Coordination Materials	ECTS Credits: 8

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:

1. Synthesis of metal complexes:
2. Analytical characterization of metal complexes (thermal analysis, UV/vis spectroscopy, cyclic voltammetry, X-ray diffraction)
3. Functional coordination materials (spin-crossover materials, information storage materials)
4. Catalysis (oxidation reactions)

Learning Outcomes / Competences:
The students will learn how to:

- prepare transition metal complexes employing modern preparation techniques (e.g. microwave synthesis), inert synthesis conditions (Schlenk technique),
- characterize coordination compounds by selected analytical techniques,
- develop functional coordination materials based on organic / inorganic hybrid compounds,
- screen metal complexes in catalytic reactions,
- employ X-ray diffraction methods for structural analysis.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
120 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)

Conditions: none		**Credit Requirements:** written report (protocols)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Coordination Materials (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

2. Part of the Module: Method Course: Coordination Materials (Seminar)
Mode of Instruction: seminar
Language: English
Contact Hours: 2

Literature:

- Chemical databases
- Primary literature

Examination

Method Course: Coordination Materials (Seminar)

seminar

Module PHM-0147: Method Course: Electron Microscopy		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
Contents: 1. Scanning electron microscopy (SEM) 2. Transmission electron microscopy (TEM)		
Learning Outcomes / Competences: The students: • 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, • are able to characterize materials using different electron microscopy techniques and to decide, if the technique is feasible for a certain problem.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h 150 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
Conditions: Recommended: knowledge of solid-state physics, reciprocal lattice		**Credit Requirements:** written report (one report per group)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Method Course: Electron Microscopy **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 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

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

Mode of Instruction: internship

Language: English

Contact Hours: 4

Examination

Method Course: Electron Microscopy

Module PHM-0146: Method Course: Electronics for Physicists and Materials Scientists		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Andreas Hörner		

Contents:

1. Basics in electronic and electrical engineering [4]
2. Quadrupole theory [2]
3. Analog technique, transistor and opamp circuits [5]
4. Boolean algebra and logic [4]
5. Digital electronics and calculation circuits [6]
6. Microprocessors and Networks [4]
7. Basics in Electronic [8]
8. Implementation of transistors [8]
9. Operational amplifiers [8]
10. Digital electronics [8]
11. Practical circuit arrangement [8]

Learning Outcomes / Competences:
The students:

- know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the laboratory,
- have skills in easy circuit design, measuring and control technology, analog and digital electronics,
- have expertise in independent working on circuit problems. They can calculate and develop easy circuits.

Remarks:
ELECTIVE COMPULSORY MODULE

Attendance in the **Method Course: Electronics for Physicists and Materials Scientists (combined lab course AND lecture)** excludes credit points for the lecture **Electronics for Physicists and Materials Scientists.**

Workload:
Total: 240 h
140 h studying of course content using provided materials (self-study)
100 h lecture and exercise course (attendance)

Conditions: none		**Credit Requirements:** written report (one per group)
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 7	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Electronics for Physicists and Materials Scientists
Mode of Instruction: lecture
Language: English
Contact Hours: 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)

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

Mode of Instruction: internship

Language: English

Contact Hours: 3

Assigned Courses:

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

Examination

Method Course: Electronics for Physicists and Materials Scientists

oral exam / length of examination: 30 minutes

Module PHM-0172: Method Course: Functional Silicate-analogous Materials	ECTS Credits: 8

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Henning Höppe

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

Learning Outcomes / Competences:
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.

Remarks:
ELECTIVE COPULSORY MODULE

Workload:
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 literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions:	**Credit Requirements:**
Recommended: attendance to the lecture "Advanced Solid State Materials"	written report (protocol)

Frequency:	**Recommended Semester:**	**Minimal Duration of the Module:**
each semester	from 2.	1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 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

Assigned Courses:

Method Course: Functional Silicate-analogous Materials (Practical Course) (internship)

Examination

Method Course: Functional Silicate-analogous Materials

seminar

Module PHM-0148: Method Course: Optical Properties of Solids		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer		

Contents:

Electrodynamics of solids

- Maxwell equations
- Electromagnetic waves
- Refraction and interference, Fresnel equations

FTIR spectroscopy

- Fourier transformation
- Michelson-Morley and Genzel interferometer
- Sources and detectors

Terahertz Time Domain spectroscopy

- Generation of pulsed THz radiation
- Gated detection, Austin switches

Elementary excitations in solids

- Infrared-active phonons
- Magnetic-dipole excitations
- Crystal-field excitations

Learning Outcomes / Competences:

The students:

- get to know the basic principles of far-infrared spectroscop and terahertz time-domain-spectroscopy,
- learn about fundamental physical excitations in condensed matter that can be studied by these methods,
- learn to plan and carry out complex experiments,
- learn how to evaluate and analyze optical data.

Remarks:

Workload:

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 literarture (self-study)

90 h studying of course content through exercises / case studies (self-study)

Conditions: Recommended: basic knowledge in solid-state physics, basic knowledge in electrodynamics and optics		**Credit Requirements:** written report
Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Optical Properties of Solids
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Literature:

- J.D. Jackson, Classical Electrodynamics (de Gruyter)
- N.W. Ashcroft, N.D. Mermin, Solid state physics (Saunders)
- Ch. Kittel, Introduction to solid state physics (Wiley)
- E. Hecht, Optics (Addison-Wesley Longman

Assigned Courses:

Method Course: Optical Properties of Solids (lecture)

2. Part of the Module: Method Course: Optical Properties of Solids (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Optical Properties of Solids (Practical Course) (internship)

Examination
Method Course: Optical Properties of Solids

Module PHM-0149: Method Course: Methods in Biophysics		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Dr. Stefan Thalhammer		
Contents: Unit radiation biophysics • Concepts in radiation protection • Low-dose irradiation biophysics • DNA repair dynamics of living cells after ionizing radiation • Confocal scanning laser microscopy Unit microfluidic • Microfluidic systems • Accoustic driven microfluidics • Calculation of microfluidic problems Unit analysis		
Learning Outcomes / Competences: The students: • know basic terms, concepts and phenomena in radiation biophysics, • acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic analytical systems, • learn skills in tissue culture and immun-histochemical staining procedures, • learn skills in fluorescence and confocal scanning microscopy, • learn skills to calculate fluidic problems on small length scales, • learn skills to handle microfluidic channel systems.		
Remarks: **ELECTIVE COMPULSORY MODULE** The course will partly take place at the Helmholtz Center Munich.		
Workload: Total: 240 h		
Conditions: Attendance of the lecture "Biophysics and Biomaterials"		**Credit Requirements:** 1 written lab report
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Method Course: Methods in Biophysics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 2
2. Part of the Module: Method Course: Methods in Biophysics (Practical Course) **Mode of Instruction:** internship **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, Strah-lenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle und R. Zengerle, Microfluidic platforms for lab-on-a-chip applica-tions, 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

Module PHM-0150: Method Course: Spectroscopy on Condensed Matter		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Dr. Stephan Krohns		
Contents: Dielectric Spectroscopy [8] • Methods • Cryo-techniques • Measurement quantities • Relaxation processes • Dielectric phenomena Ferroelectric Materials [7] • Mechanism of ferroelectric polarization • Hysteresis loop measurements • Dielectric spectroscopy Glassy Matter [8] • Introduction • Glassy phenomena • Dielectric spectroscopy Multiferroic Materials [7] • Introduction • Microscopic origins of multiferroicity • Pyrocurrent measurements • Dielectric spectroscopy		
Learning Outcomes / Competences: The students: • 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, • are trained in planning and performing complex experiments. They 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.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h		
Conditions: Recommended: basic knowledge in solid state physics, basic knowledge in physics of glasses and supercooled liquids		**Credit Requirements:** written report on the experiments (editing time 2 weeks)
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Spectroscopy on Condensed Matter
Mode of Instruction: lecture
Language: English
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)

Assigned Courses:

Method Course: Spectroscopy on Condensed Matter (lecture)

2. Part of the Module: Method Course: Spectroscopy on Condensed Matter (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Spectroscopy on Condensed Matter (Practical Course) (internship)

Examination
Method Course: Spectroscopy on Condensed Matter
written exam / length of examination: 120 minutes

Module PHM-0151: Method Course: Porous Materials - Synthesis and Characterization		ECTS Credits: 8

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:
Synthesis of porous functional materials (e.g. Metal-Organic Frameworks, zeolites)

Characterization methods

- Thermal analysis (TGA, EGA)
- Structure determination (XRD, VTXRPD)
- Absorption and diffusion (BET, pulse chemisorption)
- Catalytic properties (UV/VIS, TPO, TPR)
- Computational Modeling (calculation and predictions of framework structures)

Learning Outcomes / Competences:
The students will learn how to

- use modern solid state preparation techniques (e.g. microwave synthesis),
- employ analytical methods dedicated to porous materials.

Remarks:
ELECTIVE COMPULSORY MODULE

further information upon request

Workload:
Total: 240 h
120 h lecture and exercise course (attendance)
20 h studying of course content using literarture (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)

Conditions: Recommended: lecture Functional Porous Materials		**Credit Requirements:** written report (editing time 1 week)
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Porous Materials Synthesis and Characterization (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Porous Materials Synthesis and Characterization (Practical Course) (internship)

Examination
Method Course: Porous Materials Synthesis and Characterization
written exam / length of examination: 45 minutes

Module PHM-0157: Method Course: X-ray and Neutron Diffraction Techniques	ECTS Credits: 8

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Wolfgang Scherer

Contents:
Subjects of the practical training and the accompanying lecture are the theoretical basics and the practical application of X-ray and neutron diffraction techniques:

Basic introduction to X-ray and neutron crystallography

X-ray/neutron scattering

Data collection and reduction techniques

Symmetry and space group determination

Structural refinements:

- The Rietveld method
- Difference Fourier synthesis

Structure determination:

- Patterson method
- Direct methods

Interpretation of structural refinement results

Electronic structure determination and analysis

Learning Outcomes / Competences:
The students:

- gain basic practical knowledge on structural characterization methods for single-crystalline and powder samples employing X-ray and neutron diffraction techniques,
- have the skill to, under guidance, perform phase-analyses and structure determinations,
- are competent to analyze the structure-property relationships of new materials.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
90 h lecture and exercise course (attendance)

Conditions: none		
Frequency: each winter semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: X-ray and Neutron Diffraction Techniques
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Literature:

- C. Hammond, The Basis of Crystallography and Diffraction, Oxford University Press Inc., New York, 2001.
- W. Clegg, A. J. Blake, R. O. Gould, P. Main, Crystal Structure Analysis, Prin-ciple and Practice, Oxford University Press Inc., New York, 2001.
- G. Giacovazzo, Fundamentals of Crystallography, Oxford University Press Inc., New York, 1994.
- R. A. Young, The Rietveld Method, Oxford University Press Inc., New York, 2002.
- W. Massa, Crystal Structure Determination, Springer, Berlin, 2004.

Assigned Courses:

Method Course: X-ray and Neutron Diffraction Techniques (lecture)

2. Part of the Module: Method Course: X-ray and Neutron Diffraction Techniques (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: X-ray and Neutron Diffraction Techniques (Practical Course) (internship)

Examination
Method Course: X-ray and Neutron Diffraction Techniques
written exam / length of examination: 90 minutes

Module PHM-0173: Method Course: Finite element modeling of multiphysics phenomena		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Markus Sause		

Contents:

- Modeling and simulation of physical processes and phenomena
- Basic concepts of FEM programs
- Generation of meshes
- Optimization strategies
- Selection of solvers
- Examples from electrodynamics
- Examples from thermodynamics
- Examples from continuum mechanics
- Examples from fluid dynamics

Learning Outcomes / Competences:

- Students know established numerical procedures to model and simulate physical processes and systems
- Students acquire abilities to build numerical models based on real world challenges
- Students learn basic operational principles of FEM tools based on the program „COMSOL Multiphysics“

Remarks:

ELECTIVE COMPULSORY MODULE

This module is provided by external lecturers and lecturers from the mathematics and physics department. It is dedicated to materials scientists, physicists and engineers who intend to strengthen their background in numerical simulation using state-of-the-art FEM programs.

Workload:

Total: 240 h

120 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 literarture (self-study)

20 h studying of course content using provided materials (self-study)

Conditions: Recommended: basic knowledge of numerical cocepts		**Credit Requirements:** 1 written report on selected topic, editing time 2 weeks
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Finite element modeling of multiphysics phenomena

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Assigned Courses:

Method Course: Finite element modeling of multiphysics phenomena (lecture)

2. Part of the Module: Method Course: Finite element modeling of multiphysics phenomena (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 3

Assigned Courses:

Method Course: Finite element modeling of multiphysics phenomena (Tutorial) (exercise course)

Examination

Method Course: Finite element modeling of multiphysics phenomena

Module PHM-0153: Method Course: Magnetic and Superconducting Materials		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Philipp Gegenwart		

Contents:

Methods of growth and characterization:

Sample preparation (bulk materials and thin films), e.g.,

- arcmelting
- flux-growth
- sputtering and evaporation

Sample characterization, e.g.,

- X-ray diffraction
- electron microscopy, scanning tunneling microscopy
- magnetic susceptibility, electrical resistivity
- specific heat

Learning Outcomes / Competences:

The students

- 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
- are trained in planning and performing complex experiments
- 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

Workload:

Total: 240 h

30 h studying of course content using provided materials (self-study)

30 h studying of course content using literarture (self-study)

90 h studying of course content through exercises / case studies (self-study)

90 h lecture and exercise course (attendance)

Conditions: Recommended: basic knowledge in solid state physics and quantum mechanics		**Credit Requirements:** presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Magnetic and Superconducting Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 2

2. Part of the Module: Method Course: Magnetic and Superconducting Materials (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

Examination
Method Course: Magnetic and Superconducting Materials

Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy		ECTS Credits: 8
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Leo van Wüllen		
Contents: Physical foundations of NMR spectroscopy [6] Internal interactions in NMR spectroscopy [6] • Chemical shift interaction • Dipole interaction and • Quadrupolar interaction Magic Angle Spinning techniques [4] Modern applications of NMR in materials science [14] Experimental work at the Solid-State NMR spectrometers, computer-aided analysis and interpretation of acquired data [60]		
Learning Outcomes / Competences: The students: • gain basic knowledge of the physical foundations of modern Solid-State NMR spectroscopy, • gain basic practical knowledge of operating a solid-state NMR spectrometer, • can -- under guidance -- plan, perform, and analyze modern solid-state NMR experiments for the structural characterization of advanced materials.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literarture (self-study) 30 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
Conditions: none		
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Method Course: Modern Solid State NMR Spectroscopy

Mode of Instruction: lecture
Language: English
Contact Hours: 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.

Assigned Courses:

Method Course: Modern Solid State NMR Spectroscopy (lecture)

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

Mode of Instruction: internship

Language: English

Contact Hours: 4

Assigned Courses:

Method Course: Modern Solid State NMR Spectroscopy (Practical Course) (internship)

Examination

Method Course: Modern Solid State NMR Spectroscopy

written exam / length of examination: 90 minutes

Module PHM-0158: Introduction to Materials (= Seminar)		ECTS Credits: 4
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
Contents: Varying topics for each year, giving an overview into scope, application, requirements and preparation of all types of modern materials.		
Learning Outcomes / Competences: The students: • know the major principles, applications and processes of modern materials, • acquire the competence to compile knowledge for examples of material specific topics and to present this knowledge in given time to an audience.		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 120 h		
Conditions: Recommended: basic knowledge in materials science		**Credit Requirements:** presentation with term paper (30 - 45 minutes)
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Examination
Introduction to Materials

Module PHM-0159: Laboratory Project		ECTS Credits: 10
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: Experimental or theoretical work in a laboratory / research group in the Institute of Physics. Has to be conducted within 3 months.		
Learning Outcomes / Competences: The students: • know the basic terms, skills and concepts to pursuit a real research project in the existing laboratories within the research groups, • experience the day to day life in a research group from within, • prepare themselves to conduct a research project during their Masters thesis.		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 300 h		
Conditions: Recommended: solid knowledge in (solid state) Physics, Chemistry and Materials Science, both experimentally and theoretically		**Credit Requirements:** 1 written report (editing time 2 weeks)
Frequency: each semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 0 semester[s]
Contact Hours: 8	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Laboratory Project **Mode of Instruction:** internship **Language:** English **Contact Hours:** 8
Literature: • Various

Examination
Laboratory Project project work, not graded

Module PHM-0051: Biophysics and Biomaterials		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Stefan Thalhammer		
Contents: • Radiation Biophysics • Microfluidics • Membranes • Membranal transport		
Learning Outcomes / Competences: The students: • learn basic terms, concepts and phenomena of biological physics, • learn models of the (bio)polymer-theory, microfluidic, radiation biophysics, nanobiotechnology, membranes and neuronal networks, • adapt skills in the independent processing of problems and deal with current literature. They will be able to translate a biological oberservation into a physical question. • 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.		
Workload: 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 literarture (self-study)		
Conditions: Mechanics, Thermodynamics, Statistical Physics, basic knowledge in Molecular Biology		
Frequency: each semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Biophysics and Biomaterials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 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

Assigned Courses:

Biophysics and Biomaterials (lecture)

2. Part of the Module: Biophysics and Biomaterials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Biophysics and Biomaterials (Tutorial) (exercise course)

Examination

Biophysics and Biomaterials

written exam / length of examination: 90 minutes

Module PHM-0160: Dielectric and Optical Materials	ECTS Credits: 6

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Joachim Deisenhofer

Contents:
Optical materials:

- Fundamentals of electromagnetic wave propagation in homogenous media (refraction, reflection, transmission, absorption)
- Evanescent phenomena, optical waveguides, photonic crystals, plasmonics
- Luminescence, optoelectronics, laser
- Anisotropic media, non-linear optics

Dielectric materials:

- Dielectric properties of polar oxides: mechanism of polarization, piezoeletricity, ferroelectric polarization
- Ferroelectric materials: application of ferroelectric and relaxor-ferroelectric materials (e.g. capacitors, actuators, sensors)
- Multiferroic materials: mechanisms, materials, applications (e.g. sensors, integrated circuits)
- Supercapacitors: fundamentals of capacitance (e.g. Helmholtz- Gouy-, Chapman-, Stern-Layers), pseudo- and electrostatic capacitance, materials for supercapacitors (e.g. ionic liquids)

Learning Outcomes / Competences:
Students know the fundamentals of electromagnetic wave propagation and have a sound background for a broad spectrum of dielectric and optical phenomena. They are able to analyze materials requirements and have the competence to select materials for different kinds of applications.

Remarks:
Elective compulsory module

Workload:
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)

Conditions: Basic knowledge of solid state physics		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Dielectric and Optical Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Examination
Dielectric and Optical Materials
written exam / length of examination: 90 minutes

Module PHM-0059: Magnetism		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Hans-Albrecht Krug von Nidda		
Contents: • History, basics • Magnetic moments, classical and quantum phenomenology • Exchange interaction and mean-field theory • Magnetic anisotropy and magnetoelastic effects • Thermodynamics of magnetic systems and applications • Magnetic domains and domain walls • Magnetization processes and micro magnetic treatment • AC susceptibility and ESR • Spintransport / spintronics • Recent problems of magnetism		
Learning Outcomes / Competences: The students: • 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, • have the ability to classify different magnetic phenomena and to apply the corresponding models for their interpretation, and • have the competence independently to treat fundamental and typical topics and problems of magnetism. • Integrated acquirement of soft skills.		
Workload: 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)		
Conditions: basics of solid-state physics and quantum mechanics		
Frequency: annually	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Magnetism **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: 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 Phyics (Wiley)
- D. C. Mattis, The Theory of Magnetism (Wiley)
- G. L. Squires, Thermal Neutron Scattering (Dover Publications Inc.)

2. 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

Module PHM-0048: Physics and Technology of Semiconductor Devices	ECTS Credits: 6

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Hubert J. Krenner

Contents:

1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport)
2. Semiconductor diodes and transistors
3. Semiconductor technology
4. Optoelectronics

Learning Outcomes / Competences:

- Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport.
- Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors.
- Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes, transistors, and optically active elements (LEDs, detectors and lasers).
- Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication.
- 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.

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:
recommended prerequisites: basic knowledge in solid state physics and quantum mechanics.

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

Parts of the Module

1. Part of the Module: Physics and Technology of Semiconductor Devices
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
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)

2. 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

Module PHM-0049: Nanostructures / Nanophysics		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Hubert J. Krenner		

Contents:

1. Semiconductor quantum wells, wires and dots, low dimensional electron systems
2. Magnetotransport in low-dimensional systems, Quanten-Hall-Effect, Quantized conductance
3. Optical properties of quantum wells and quantum dots and their application in modern optoelectonic devices
4. Nanowires, Carbon Nanotubes, Graphene
5. Nanophotonics, photonic band gap materials, photonic crystals
6. Emerging concepts such as Quantum Computing and Quantum Information Processing

Learning Outcomes / Competences:

- Basic knowledge of the fundamental concepts in modern nanoscale science
- Profound knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics
- Knowledge of different fabrication approaches using bottom-up and top-down techniques
- Application of these concepts to tackle present problems in nanophysics
- 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.

Workload:

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 literarture (self-study)
60 h lecture and exercise course (attendance)

Conditions: recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
Frequency: each winter semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Nanostructures / Nanophysics
Mode of Instruction: lecture
Language: English
Frequency: each summer semester
Contact Hours: 4

Learning Outcome:

see module description

Contents:

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)
- V. V. Mitin et al.: Introduction to Nanoelectronics (Cambridge University Press)
- Yariv: Quantum Electronics (Wiley)
- Yariv und Yeh: Photonics (Oxford University Press)

Assigned Courses:

Nanostructures / Nanophysics (lecture)

Examination

Nanostructures / Nanophysics

oral exam / length of examination: 30 minutes

Module PHM-0174: Theoretical Concepts and Simulation		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Liviu Chioncel		
Contents: 1. Introduction: operating systems, programming languages, data visualization tools 2. Basic numerical methods: interpolation, integration 3. Ordinary and Partial Differential Equations (e.g., diffusion equation, Schrödinger equation) 4. Molecular dynamics 5. Monte Carlo simulations		
Learning Outcomes / Competences: The students: • know the principal concepts of thermodynamics and statistical physics as well as the numerical methods relevant in material science, • are able to solve simple problems numerically. They are able to write the codes and to present the results, • have the expertise to find the numerical method appropriate for the given problem and to judge the quality and validity of the numerical results, • 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 present the results in written and oral form, capacity for teamwork.		
Remarks: Links to software related to the course: • http://www.bloodshed.net/ • http://www.cplusplus.com/doc/tutorial/ • http://www.cygwin.com/ • http://xmd.sourceforge.net/download.html • http://www.rasmol.org/ • http://felt.sourceforge.net/		
Workload: Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Recommended: basic knowledge of quantum mechanics, thermodynamics, and numerical methods as well as of a programming language		**Credit Requirements:** project work in small groups, including a written summary of the results (ca. 10-20 pages) as well as an oral presentation
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Theoretical Concepts and Simulation

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

- Tao Pang, An Introduction to Computational Physics (Cambridge University Press)
- J. M. Thijssen, Computational Physics (Cambridge University Press)
- Koonin, Meredith, Computational Physics (Addison-Weseley)
- D. C. Rapaport, The Art of Molecular Dynamics Simulation, (Cambridge University Press)
- W. H. Press et al, Numerical Recipes (Cambridge University Press)

2. Part of the Module: Theoretical Concepts and Simulation (Project)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Theoretical Concepts and Simulation

seminar / length of examination: 30 minutes

Module PHM-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons	ECTS Credits: 6

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Christine Kuntscher

Contents:

1. Electromagnetic radiation: description, generation, detection [5]
2. Spectral analysis of electromagnetic radiation: monochromators, spectrometer, interferometer [2]
3. Excitations in the solid state: Dielectric function [2]
4. Infrared spectroscopy
5. Ellipsometry
6. Photoemission spectroscopy
7. X-ray absorption spectroscopy
8. Neutrons: Sources, detectors
9. Neutron scattering

Learning Outcomes / Competences:
The students:

- know the basics of spectroscopy and important instrumentation and methods,
- have acquired the skills of formulating a mathematical-physical ansatz in spectroscopy and can apply these in the field of solid state spectroscopy,
- have the competence to deal with current problems in solid state spectroscopy autonomously, and are able to judge proper measurement methods for application.
- Integrated acquirement of soft skills.

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:
basic knowledge in solid-state physics

Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
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)

2. 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

Module PHM-0056: Ion-Solid Interaction		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: • Introduction (areas of scientific and technological application, principles) • Fundamentals of atomic collision processes (scattering, cross-sections, energy loss models, potentials in binary collision models) • 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) • Transport phenomena • Analysis with ion beams		
Learning Outcomes / Competences: The students: • know the physical principles and the basical mechanisms of the interaction between particles and solid state bodies in the energy range of eV to MeV, • are able to choose adequate physical models for specific technological and scientific applications, and • have the competence to work extensively autonomous on problems concerning the interaction between ions and solid state bodies. • Integrated acquirement of soft skills.		
Workload: Total: 180 h 20 h studying of course content using literarture (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)		
Conditions: Basic Courses in Physics I–IV, Solid State Physics, Nuclear Physics		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Ion-Solid Interaction **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: 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

2. 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

Module PHM-0057: Physics of Thin Films		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. German Hammerl		
Contents: • Layer growth • Thin film technology • Analysis of thin films • Properties and applications of thin films		
Learning Outcomes / Competences: The students: • know methods of thin film technology and material properties and applications of thin films, • have acquired skills of grouping the various technologies for producing thin layers with respect to their properties and applications, and • have the competence to deal with current problems in the field of thin film technology largely autonomous. • Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results.		
Workload: Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: none		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** 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 **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)
Assigned Courses:

Physics of Thin Films (lecture)

Examination

Physics of Thin Films

written exam / length of examination: 90 minutes

Module PHM-0058: Organic Semiconductors	ECTS Credits: 6

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Wolfgang Brütting

Contents:
Introduction

- Materials and preparation
- Structural properties
- Electronic structure
- Optical and electrical properties

Devices and Applications

- Organic metals
- Light-emitting diodes
- Field-effect transistors
- Solar cells and laser

Learning Outcomes / Competences:
The students:

- know the basic structural and electronic properties of organic semiconductors as well as the essential function of organic semiconductor devices,
- have acquired skills for the classification of the materials taking into account their specific features in the functioning of components,
- and have the competence to comprehend and attend to current problems in the field of organic electronics.
- Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:
It is strongly recommended to complete the module solid-state physics first. In addition, knowledge of molecular physics is desired.

Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Organic Semiconductors
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:

see module description

Literature:

- M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)
- W. Brütting (editor): Physics of Organic Semiconductors (Wiley-VCH)
- A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)

2. Part of the Module: Organic Semiconductors (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Organic Semiconductors

written exam / length of examination: 90 minutes

Module PHM-0060: Low Temperature Physics		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: PD Dr. Reinhard Tidecks		
Contents: • Introduction • Thermodynamic fundamentals • Gas liquification • Properties of liquid helium • Cryogenic engineering		
Learning Outcomes / Competences: The students: • know the basic properties of matter at low temperatures and the corresponding experimental techniques, • have acquired the theoretical knowledge to perform low-temperature measurements, • and know how to experimentally investigate current problems in low-temperature physics.		
Workload: 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 literarture (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: Physik IV - Solid-state physics		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Low Temperature Physics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Introduction

  - History, methods, realizations, and significance

- Thermodynamic fundamentals

  - Temperature, working cycles, real gases, Joul-Thomson-Effect

- Gas liquification

  - Air, hydrogen, helium
  - Separation of Oxygen and nitrogen
  - Storage and transfer of liquefied gases, superinsulation

- Properties of liquid helium

  - Production and thermodynamic properties of4He and3He
  - Phase diagrams (4He,3He)
  - Superfluidity of4He
    - Experiments, Two-Fluid-Model
    - Bose-Einstein-Condensation
    - Excitation spectrum, critical velocity
    - Rotating Helium
  - Normal and superfluid3He
  -4He /3He-mixtures

- Cryogenic engineering

  - Bath-Cryostats (Helium-4, Helium-3),
  -4He /3He-Dilution-Refrigerators
  - Pomeranchuck-Cooling
  - Adiabatic demagnetization
  - Primary and secondary thermometers

Literature:

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

2. Part of the Module: Low Temperature Physics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Low Temperature Physics

oral exam / length of examination: 30 minutes

Module PHM-0068: Spintronics		ECTS Credits: 6
Version 1.0.0 (since SoSe14) Person responsible for module: Dr. German Hammerl		
Contents: • Introduction into magnetism • Basic spintronic effects and devices • Novel materials for spintronic applications • Spin-sensitive experimental methods • Semiconductor based spintronics		
Learning Outcomes / Competences: The students: • know the fundamental properties of magnetic materials, the basic spintronic effects, and the related device structures, • have acquired skills in identifying materials with respect to their applicability for spintronic devices, • and have the competence to deal with current problems in the field of semi-conductor and metal based spintronics largely autonomous.		
Workload: 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 literarture (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Spintronics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 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

2. Part of the Module: Spintronics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Spintronics

written exam / length of examination: 90 minutes

Module PHM-0066: Superconductivity		ECTS Credits: 6
Version 1.0.0 (since WS11/12) Person responsible for module: PD Dr. Reinhard Tidecks		
Contents: • Introductory Remarks and Literature • History and Main Properties of the Superconducting State, an Overview • Phenomenological Thermodynamics and Electrodynamics of the SC • Ginzburg-Landau Theory • Microscopic Theories • Fundamental Experiments on the Nature of the Superconducting State • Josephson-Effects • High Temperature Superconductors • Application of Superconductivity		
Learning Outcomes / Competences: The students: • will get an introduction to superconductivity, • by a presentation of experimental results they will learn the fundamental properties of the superconducting state, • are informed about the most important technical applications of superconductivity. • 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. • For self-studies a comprehensive list of further reading will be supplied.		
Workload: 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 literarture (self-study)		
Conditions: • Physik IV – Solid-state physics • Theoretical physics I-III		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Superconductivity **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: see module description
Contents: 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

Assigned Courses:

Superconductivity (lecture)

Examination

Superconductivity

oral exam / length of examination: 30 minutes

Module PHM-0069: Applied Magnetic Materials and Methods		ECTS Credits: 6
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Manfred Albrecht		
Contents: • Basics of magnetism • Ferrimagnets, permanent magnets • Magnetic nanoparticles • Superparamagnetism • Exchange bias effect • Magnetoresistance, sensors • Experimental methods (e.g. Mößbauer Spectroscopy, mu-SR)		
Learning Outcomes / Competences: • The students know the basic terms and concepts of magnetism, • get a profound understanding of basic physical relations and their applications, • acquire the ability to describe qualitative observations, interpret quantitative measurements, and develop mathematical descriptions of physical effects of chosen magnetic material systems. • 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.		
Workload: 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 literarture (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Basics in solid state physics		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Applied Magnetic Materials and Methods **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: see module description
Literature: to be announced at the beginning of the lecture
Assigned Courses: **Applied Magnetic Materials and Methods** (lecture)

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Applied Magnetic Materials and Methods (Tutorial) (exercise course)

Examination

Applied Magnetic Materials and Methods

oral exam / length of examination: 30 minutes

Module PHM-0198: Special Topics in Materials Science (Foreign Institution)		ECTS Credits: 20
Version 1.0.0 Person responsible for module: Prof. Dr. Ferdinand Haider		
Conditions: studies at an international partner institution		**Credit Requirements:** written exam, oral exam, report, etc.
Frequency: each semester	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
	Repeat Exams Permitted: according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Special Topics in Materials Science (Foreign Institution) **Language:** English

Examination
Special Topics in Materials Science (Foreign Institution) module exam, written exam, oral exam, report, etc.

Module PHM-0054: Chemical Physics II		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer		
Contents: • Charge density distribution from experiment and theory • Analysis of topology of spin- and charge density distribution • The nature of chemical bondings • Analysis of wave functions with localized orbitals • Modern quantum chemical methods: configuration interaction		
Learning Outcomes / Competences: The students: • know the basic quantum chemical methods of chemical physics to interpret electronical structures in molecules and solid-state bodies, • have therefore the ability to apply amongst other things the quantum theory of atoms in molecules (QTAIM) and established electron localization functions (such as ELF) to analyze charge- and spin density distributions, • have the competence to do autonomously simple quantum chemical calculations using the density functional theory (DFT) and to interpret the electronical structure of functional molecules and materials with regard to chemical and physical properties. • Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.		
Remarks: 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.		
Workload: 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 literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: It is highly recommended to complete the module Chemical Physics I first.		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Chemical Physics II **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Charge density distribution from experiment and theory
- Analysis of topology of spin- and charge density distribution
- The nature of chemical bondings
- Analysis of wave functions with localized orbitals
- Modern quantum chemical methods: configuration interaction

Literature:

- J. Reinhold, Quantentheorie der Moleküle (Teubner)
- H.-H. Schmidtke, Quantenchemie (VCH)
- J. K. Burdett, Chemical Bonds: A Dialog (Wiley)
- F. A. Kettle, Physical Inorganic Chemistry (Oxford University Press)
- R. F. W. Bader, Atoms in Molecules: A Quantum Theory (Oxford University Press)
- P. Popelier, Atoms in Molecules: An Introduction(Pearson Education Limited)
- F. Weinhold, C. R. Landis, Valency and Bonding: A Natural Bond Orbital Donor-Acceptor Perspective (Cambridge University Press)
- A. Frisch, Exploring Chemistry with Electronic Structure Methods (Gaussian Inc. Pittsburg, PA)

2. 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

Module PHM-0161: Coordination Materials		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		

Contents:

A)

- Historical development of coordination chemistry [1]
- Structures and nomenclature rules [2]
- Chemical bonds in transition metal coordination compounds [3]
- Stability of transition metal compounds [2]
- Characteristic reactions [4]B

B) Selected classes of functional materials

- Bioinorganic chemistry [2]
- Coordination compounds in medical applications [1]
- Coordination polymers / metal-organic frameworks [4]
- Cluster compounds [2]

Learning Outcomes / Competences:

The students

- shall acquire knowledge about concepts of chemical bonding in coordination chemistry (main emphasis: d-block transition metal compounds),
- broaden their capabilities to interpret UV/vis absorption spectra and to predict stability and reactivity of coordination compounds,
- learn how to transfer concepts of coordination chemistry onto topics of materials sciences.
- Integrated acquirement of soft skills.

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

Total: 180 h

20 h studying of course content using provided materials (self-study)

20 h studying of course content using literarture (self-study)

80 h studying of course content through exercises / case studies (self-study)

60 h lecture and exercise course (attendance)

Conditions: Recommended: The lecture course is based on the courses "Chemistry I", "Chemistry II"		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Coordination Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

- Joan Ribas Gisbert, Coordination Chemistry, Wiley-VCH
- Lutz H. Gade, Koordinationschemie, Wiley-VCH
- As well as selected reviews and journals articles cited on the slides

2. Part of the Module: Coordination Materials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Coordination Materials

written exam / length of examination: 90 minutes

Module PHM-0113: Advanced Solid State Materials		ECTS Credits: 6
Version 1.0.0 (since WS10/11) Person responsible for module: Prof. Dr. Henning Höppe		
Contents: • Repitition of concepts • Novel silicate-analogous materials • Luminescent materials • Pigments • Heterogeneous catalysis		
Learning Outcomes / Competences: • The students are aware of correlations between composition, structures and properties of functional materials, • acquire skills to predict the properties of chemical compounds, based on their composition and structures, • gain competence to evaluate the potential of functional materials for future technological developments, and • will know how to measure the properties of these materials. • Integrated acquirement of soft skills		
Workload: 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 literarture (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Contents of the modules Chemie I, and Chemie II or Festkörperchemie (Bachelor Physik, Bachelor Materialwissenschaften)		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Advanced Solid State Materials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: see module description
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

Module PHM-0162: Solid State NMR Spectroscopy and Diffraction Methods		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Georg Eickerling		
Contents: Physical foundations of NMR spectroscopy Internal Interactions in solid state NMR spectroscopy Magic Angle Spinning NMR Basic Introduction to X-ray and neutron diffraction and crystallography X-ray/neutron scattering Data collection and reduction techniques Symmetry and space group determination Structure determination and refinement • The Patterson method • Direct methods • Rietveld refinements • Difference Fourier techniques • Charge density determination/analysis		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: 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 literarture (self-study)		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Solid State NMR Spectroscopy and Diffraction Methods **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3

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.
5. C. Hammond, The Basis of Crystallography and Diffraction, Oxford University Press Inc., New York, 2001.
6. W. Clegg, A. J. Blake, R. O. Gould, P. Main, Crystal Structure Analysis, Principle and Practice, Oxford University Press Inc., New York, 2001.
7. G. Giacovazzo, Fundamentals of Crystallography, Oxford University Press Inc., New York, 1994.
8. R. A. Young, The Rietveld Method, Oxford University Press Inc., New York, 2002.
9. W. Massa, Crystal Structure Determination, Springer, Berlin, 2004.

2. Part of the Module: Solid State NMR Spectroscopy and Diffraction Methods (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Solid State NMR Spectroscopy and Diffraction Methods

written exam / length of examination: 90 minutes

Module PHM-0114: Porous Functional Materials	ECTS Credits: 6

Version 1.0.0 (since SS11)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:

- Overview and historical developments
- Structural families of porous frameworks
- Structure Determination and Computer Modelling
- Synthesis strategies
- Adsorption and diffusion
- Thermal analysis methods
- Catalytic properties
- Advanced applications and current trends

Learning Outcomes / Competences:

- The students shall acquire knowledge about design principles and synthesis of porous functional materials,
- broaden their capabilities to characterize porous solid state materials with special emphasis laid upon sorption and thermal analysis,
- become introduced into typical technical applications of porous solids.
- Integrated acquirement of soft skills

Remarks:
Subsequent to the lecture course, the students can take part in a hands-on method course ``Porous Materials Synthesis and Characterization'' to practice their knowledge.

Workload:
Total: 180 h
20 h studying of course content using literarture (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)

Conditions: participation in the course Materials Chemistry		**Credit Requirements:** one written examination, 90 min
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Porous Functional Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Contents:
see module description

Literature:

- Paul A. Wright, Microporous Framework Solids (RSC Materials Monographs, 2008)
- selected reviews and journal articles cited on the slides

Assigned Courses:

Porous Functional Materials (lecture)

Examination

Porous Functional Materials

written exam / length of examination: 90 minutes

Module PHM-0167: Oxidation and Corrosion	ECTS Credits: 6

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Ferdinand Haider

Contents:

Introduction

Review of thermodynamics

Chemical equilibria

Electrochemistry

Electrode kinetics

High temperature oxidation

Localized corrosion

- Shallow pit corrosion
- Pitting corrosion
- Crevice corrosion
- Intercrystalline corrosion
- Stress corrosion cracking
- Fatigue corrosion
- Erosion corrosion
- Galvanic corrosion

Water and seawater corrosion

Corrosion monitoring

Corrosion properties of specific materials

Specific corrosion problems in certain branches

- Oil and Gas industry
- Automobile industry
- Food industry

Corrosion protection

- Passive layers
- Reaction layers (Diffusion layers …)
- Coatings (organic, inorganic)
- Cathodic, anodic protection
- Inhibitors

Learning Outcomes / Competences:

The students:

- know the the fundamental basics, mechanics, and types of corrosion processes,
- obtain specific knowledge of one type of corrosion.

Workload:

Total: 168 h
100 h studying of course content using provided materials (self-study)
68 h lecture and exercise course (attendance)

Conditions:	Credit Requirements:
Recommended: good knowledge in materials science, basic knowledge in physical chemistry	practical course, written report

Frequency:	Recommended Semester:	Minimal Duration of the Module:

each winter semester	from 3.	1 semester[s]
Contact Hours: 5	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Oxidation and Corrosion

Mode of Instruction: lecture

Language: English

Contact Hours: 4

Literature:

- Schütze: Corrosion and Environmental Degradation

Assigned Courses:

Oxidation and Corrosion (lecture)

2. Part of the Module: Oxidation and Corrosion (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Oxidation and Corrosion (Tutorial) (exercise course)

Examination

Oxidation and Corrosion

written exam / length of examination: 90 minutes

Module PHM-0198: Special Topics in Materials Science (Foreign Institution)		ECTS Credits: 20
Version 1.0.0 Person responsible for module: Prof. Dr. Ferdinand Haider		
Conditions: studies at an international partner institution		**Credit Requirements:** written exam, oral exam, report, etc.
Frequency: each semester	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
	Repeat Exams Permitted: according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Special Topics in Materials Science (Foreign Institution) **Language:** English

Examination
Special Topics in Materials Science (Foreign Institution) module exam, written exam, oral exam, report, etc.

Module PHM-0164: Characterization of Composite Materials		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Markus Sause		
Contents: The following topics are presented: • Introduction to composite materials • Applications of composite materials • Mechanical testing • Thermophysical testing • Nondestructive testing		
Learning Outcomes / Competences: The students: • acquire knowledge in the field of materials testing and evaluation of composite materials. • are introduced to important concepts in measurement techniques, and material models applied to composites. • are able to independently acquire further information of the scientific topic using various forms of information.		
Workload: 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 literarture (self-study)		
Conditions: Recommended: basic knowledge in materials science, particularly in composite materials		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Characterization of Composite Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

- Morgan: Carbon fibers and their composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe
- Dowling: Mechanical behaviour of materials
- Issler: Festigkeitslehre - Grundlagen
- Landau, Lifschitz: Theoretische Physik Vol. 7

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

2. 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

Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn		
Contents: The following topics are treated: • production of fibers (e.g. glass, carbon, or ceramic fibers) • Physical and chemical properties of fibers and their precursor materials • Physical and chemical properties of commonly used polymeric and ceramic matrix materials • Semi-finished products • Composite production technologies • Application of fiber reinforced materials		
Learning Outcomes / Competences: The students: • know the application areas of composite materials. • know the basics of production technologies of fibers, polymeric, and ceramic matrices and fiber reinforced materials. • are introduced to physical and chemical properties of fibers, matrices, and fiber reinforced materials. • are able to independently acquire further knowledge of the scientific topic using various forms of information.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: 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 literarture (self-study)		
Conditions: Recommended: basic knowledge in materials science, basic lectures in organic chemistry		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

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

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

Assigned Courses:

Fiber Reinforced Composites: Processing and Materials Properties (lecture)

2. 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

Module PHM-0165: Introduction to Mechanical Engineering		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Dr. - Ing. Johannes Schilp		
Contents: The following topics are treated: • Statics and dynamics of objects • Transmissions and mechanisms • Tension, shear and bending moment • Hydrostatics • Hydrodynamics • Strength of materials and solid mechanics • Instrumentation and measurement • Mechanical design (including kinematics and dynamics)		
Learning Outcomes / Competences: The students understand and are able to apply basic concepts of physics and materials science to: • Engineering applications • Mechanical testing • Instrumentation • Mechanical design		
Workload: Total: 180 h		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Mechanical Engineering

Mode of Instruction: lecture

Language: English

Contact Hours: 3

2. Part of the Module: Mechanical Engineering (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Introduction to Mechanical Engineering

written exam / length of examination: 90 minutes

Module MRM-0052: Functional Polymers	ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Klaus Ruhland	

Contents:

- Introduction to polymer science
- Elastomers and elastoplastic materials
- Memory-shape polymers
- Piezoelectric polymers
- Electrically conducting polymers
- Ion-conducting polymers
- Magnetic polymers
- Photoresponsive polymers
- Polymers with second order non-linear optical properties
- Polymeric catalysts
- Self-healing polymers
- Polymers in bio sciences>

Learning Outcomes / Competences:

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.

Workload:

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 literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions:

Recommended: Attendance to PHM-0035 (Chemie I), PHM-0036 (Chemie II) and MRM-0050 (Grundlagen der Polymerchemie und -physik)

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

1. Part of the Module: Functional Polymers

Mode of Instruction: lecture
Language: English
Contact Hours: 3

2. Part of the Module: Functional Polymers (Tutorial)

Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Examination

Functional Polymers

written exam / length of examination: 90 minutes

Module PHM-0122: Non-Destructive Testing		ECTS Credits: 6
Version 1.0.0 (since WS14/15) Person responsible for module: Markus Sause		
Contents: • Introduction to nondestructive testing methods • Visual inspection • Ultrasonic testing • Guided wave testing • Acoustic emission analysis • Thermography • Radiography • Eddy current testing • Specialized nondestructive methods		
Learning Outcomes / Competences: The students • acquire knowledge in the field of nondestructive evaluation of materials, • are introduced to important concepts in nondestructive measurement techniques, • are able to independently acquire further knowledge of the scientific topic using various forms of information. • Integrated acquirement of soft skills		
Workload: 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 literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: Basic knowledge on materials science, in particular composite materials		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Non-Destructive Testing **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: 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)

2. 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

Module PHM-0168: Modern Metallic Materials		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		

Contents:

Introduction

Review of physical metallurgy

Steels:

- principles
- common alloying elements
- martensitic transformations
- dual phase steels
- TRIP and TWIP steels
- maraging steel
- electrical steel
- production and processing

Aluminium alloys:

- 2xxx
- 6xxx
- 7xxx
- Processing – creep forming, hydroforming, spinforming

Titanium alloys

Magnesium cast alloys

Superalloys

Intermetallics, high entropy alloys

Copper, brass, bronzes

Metallic glasses

Alloy design

Learning Outcomes / Competences:

Students

- learn about all kinds of actual metallic alloys, their properties and how these properties can be derived from basic concepts

Workload:

Total: 180 h
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)
60 h lecture and exercise course (attendance)

Conditions: Recommended: Knowledge of physical metallurgy and physical chemistry		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Module PHM-0184: Sustainable Resource Management		ECTS Credits: 6
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Armin Reller		
Learning Outcomes / Competences: • The students know the basics of geographic distribution and the technical relevancy of different resources like energy sources and metals. • Furthermore, the students know risk management methods, which are used to identify, measure and manage resource price risks. For this purpose, resource scarcity indicators, risk measures and instruments for risk protection are being presented, which enable the students to make economically well-grounded decisions in dealing with resources. • Moreover, the students know how resource-based strategies with the help of environmental management contribute to environmental risk management. All topics are being illustrated with examples (from practical projects).		
Remarks: Elective Module		
Workload: Total: 180 h 140 h studying of course content using provided materials (self-study) 40 h seminar (attendance)		
Conditions: none		**Credit Requirements:** 1 written report on selected questions of sustainable resource management (number of pages: approx. 15 - 20; editing time 2 weeks), oral presentation (30 minutes), compulsatory attandance (40 hours)
Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
1. Part of the Module: Sustainable Resource Management **Mode of Instruction:** seminar **Lecturers:** Prof. Dr. Armin Reller **Language:** English **Frequency:** each summer semester **Contact Hours:** 2 **ECTS Credits:** 4

Contents:

1. Introduction (global resource consumption)
2. Overview of resource types
3. Definition of mineral resources
4. Introduction to resource management
5. Identification of resource price risks
6. Measurement of resource price risks
7. Management of resource price risks
8. Introduction in basics of environmental management
9. Corporate environmental management
10. Economical closed-loop systems

Literature:

- Holger Rogall: Nachhaltige Ökonomie, Metropolis, Marburg, 2009.
- Hans-Dieter Haas, Dieter Matthew Schlesinger: Umweltökonomie und Res-sourcenmanagement, Wissenschaftliche Buchgesellschaft, Darmstadt, 2007.
- Colin W. Clark: Mathematical Bioeconomics, Wiley, New York, 1976.
- Werner Gocht: Handbuch der Metallmärkte, 2. Aufl., Springer, New York / Tokyo, 1985.

2. Part of the Module: Sustainable Resource Management (Tutorial)

Mode of Instruction: exercise course
Lecturers: Prof. Dr. Armin Reller
Language: English
Frequency: each summer semester
Contact Hours: 2
ECTS Credits: 2

Examination

Sustainable Resource Management

seminar

Description:

1 written report (number of pages: approx. 15 - 20; editing time 2 weeks), oral presentation (30 minutes), compulsatory attandance (40 hours)

Module PHM-0050: Electronics for Physicists and Materials Scientists		ECTS Credits: 6
Version 1.0.0 (since WS09/10) Person responsible for module: Andreas Hörner		
Contents: 1. Basics in electronic and electrical engineering 2. Quadrupole theory 3. Analog technique, transistor and opamp circuits 4. Boolean algebra and logic 5. Digital electronics and calculation circuits 6. Microprocessors and Networks 7. Basics in Electronic 8. Implementation of transistors 9. Operational amplifiers 10. Digital electronics		
Learning Outcomes / Competences: The students: • know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the Lab, • have skills in easy circuit design, measuring and control technology, analog and digital electronics, • have expertise in independent working on circuit problems. They can calculate and develop easy circuits. • 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.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (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)		
Conditions: none		
Frequency: each semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Electronics for Physicists and Materials Scientists **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: see module description
Contents: see module description

Literature:

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

Assigned Courses:

Electronics for Physicists and Materials Scientists (lecture)

Examination

Electronics for Physicists and Materials Scientists

oral exam / length of examination: 30 minutes

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

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

Module PHM-0198: Special Topics in Materials Science (Foreign Institution)		ECTS Credits: 20
Version 1.0.0 Person responsible for module: Prof. Dr. Ferdinand Haider		
Conditions: studies at an international partner institution		**Credit Requirements:** written exam, oral exam, report, etc.
Frequency: each semester	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
	Repeat Exams Permitted: according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Special Topics in Materials Science (Foreign Institution) **Language:** English

Examination
Special Topics in Materials Science (Foreign Institution) module exam, written exam, oral exam, report, etc.

Module PHM-0169: Masterthesis		ECTS Credits: 26
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: According to chosen topic		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 780 h 260 h studying of course content using provided materials (self-study) 520 h lecture and exercise course (attendance)		
Conditions: 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		**Credit Requirements:** written thesis
Frequency: each semester	**Recommended Semester:** from 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1	**Repeat Exams Permitted:** 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

Module PHM-0170: Colloquium		ECTS Credits: 4
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: According to the respective Masterthesis		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 120 h 80 h lecture and exercise course (attendance) 40 h studying of course content using provided materials (self-study)		
Conditions: submission of the masterthesis		
Frequency: each semester	**Recommended Semester:** from 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Examination
Colloquium seminar / length of examination: 20 minutes, not graded