Module Guide / Modulhandbuch

TECHNISCHE UNIVERSITÄT DARMSTADT

Department of Materials and Geo Sciences

Fachbereich Material- und Geowissenschaften

Course of Studies Master of Science Materials Science

Studiengang Master of Science Materialwissenschaft

Examination Regulations 2015

Prüfungsordnung 2015

Comments about this module guide:

- The module descriptions were extracted from TUCaN.
- Although there has been some effort to provide a purely English version of the module guide, some German Traces remain. Translations/meaning:

German	English
Language of instruction	
Deutsch	German
Englisch	English
Deutsch und Englisch	German and English
Form of instruction	
Kurs	course
Praktikum	Lab
Seminar	seminar
Übung	exercises
Vorlesung	lecture
Forms of examination / Grading	
Abgabe	handing-in written report
bausteinbegleitende Prüfung	course exam
bestanden / nicht bestanden	pass / fail
Fachprüfung	exam with only three attempts
fakultativ	written or oral exam
Gewichtung	weight
Modulabschlussprüfung, Modulprüfung	module exam
mündliche / schriftliche Prüfung	written or oral exam
Referat	presentation
Standard (in context of grading)	grading 1(very good) - 5 (fail)
Studienleistung	exam without limitation on attempts

- Some entries of some modules may be missing. This does not necessarily have an implication on the availability of the respective module.
- Please be aware that the elective courses within this module guide cannot be guaranteed to be available in the future. For a number of reasons, e.g. the coming and leaving of professors and other lecturers, some modules may become temporarily or permanently unavailable, others may be added without immediately showing up in this list.
- Besides Materials Science courses from the Department of Materials and Geosciences only selected modules from the Geosciences part of the department and no modules from other departments are included in this guide, even though they may fit into your individual plan for “Elective Courses Materials Science.” Please discuss this plan with your mentor.
- There is a mandatory elective domain “Quantum Mechanics/Micromechanics” with a choice between the modules “Quantum Mechanics for Materials Science” and “Micromechanics for Materials Science.” The module not elected in this domain becomes part of the domain “Elective Courses Materials Science” and may be chosen there.
- The module “Concepts in Materials Physics” repeats contents from the Bachelor course Materials Science of TU Darmstadt and must therefore not be taken for credit by graduates of this course. Most international students that are not part of double degree programs are required to take this course.
- The durations of the exams and the courses’ credit points cannot be extracted correctly yet. The respective information may be obtained from the Studien- und Prüfungsplan (Schedule of Studies and Exams), available on the departmental web pages within the Studienordnung (study regulations).

- Another consequence is that a table of contents is missing at this point. The ordering of modules within this guide can be found in the table on the following page
- Registration to the Master Thesis module is not possible online, but needs to be carried out by the Materials Science office of student affairs.

PD Dr. Boris Kastening, coordinator of studies

Last update: 08 Jnue 2021

Domain	Module no.	Module name	Cycle
Mandatory Courses Materials Science		Master Thesis	WS & SS
	11-01-4101	Research Lab I	WS
	11-01-4102	Research Lab II	SS
	11-01-4103	Advanced Research Lab & Seminar	WS & SS
	11-01-4104	Functional Materials	WS
	11-01-4105	Surfaces and Interfaces	WS
	11-01-4106	Theoretical Methods in Materials Science	SS
	11-01-4107	Advanced Characterization Methods of Materials Science	SS
QM/MM	11-01-4108	Quantum Mechanics for Materials Science	WS
	11-01-4109	Micromechanics for Materials Science	WS
Elective Courses Materials Science	11-01-2009	Concepts in Materials Physics (choose only if Bachelor degree is not Materials Science from TU Darmstadt)	WS
	11-01-3029	Advanced Light Microscopy	SS
	11-01-8191	Ceramic Materials: Syntheses and Properties. Part I	SS
	11-01-7342	Ceramic Materials: Syntheses and Properties. Part II	WS
	11-01-9811	Characterization Methods in Materials Science - Neutrons and Synchrotron	as needed /on request
	11-01-8241	Chemical Sensors: Basics and Applications	SS
	11-01-7562	Computational Materials Science	WS
	11-01-2020	Computer Models of Solid Materials	SS
	11-01-9902	Course Processing of Conventional and Polymer Derived Silicon Ceramics	WS
	11-01-8291	Density Functional Theory: A Practical Introduction	SS
	11-01-2025	Dislocations in Ceramics	SS
	11-01-7300	Electrochemistry in Energy Applications I: Converter Devices	SS
	11-01-7301	Electrochemistry in Energy Applications II: Storage Devices	WS
	11-02-9052	Elektronenkristallographie I	WS
	11-02-9053	Elektronenkristallographie II	SS
	11-01-8131	Engineering Microstructures	WS
	11-01-9063	Focused Ion Beam Microscopy: Basics and Applications	WS
	11-01-8202	Fundamentals and Techniques of Modern Surface Science	WS
	11-01-2005	Fundamentals and Technology of Solar Cells	SS
	11-01-2008	Graphen and Carbon Nanotubes - from fundamentals to applications	SS
	11-01-7602	High Pressure Materials Synthesis	SS
	11-01-2024	Hysteresis in Magnetic Materials	SS
	11-01-2017	In-situ Transmission Electron Microscopy	SS
	11-01-2016	Interfaces: Wetting and Friction	SS
	11-01-2001	Magnetism and Magnetic Materials	WS
	11-01-7292	Materials Chemistry	WS
	11-01-2022	Materials chemistry in electrocatalysis for energy applications	SS
	11-01-7042	Materials Research with Energetic Ion Beams - Basic Aspects and Nanotechnology	SS
	11-01-2004	Materials Science of Thin Films	SS
	11-01-3018	Mathematical Methods in Materials Science	WS
	11-01-9332	Mechanical Properties of Ceramic Materials	WS
	11-01-2006	Mechanical Properties of Metals	WS
	11-01-7070	Micromechanics and Nanostructured Materials	WS & SS
	11-01-9090	Modern Steels for Automotive Applications	SS
	11-01-2026	Organic Functional Materials: From LCD to Molecular Circuits	WS
	11-01-9812	Phase Transition in Materials	SS
	11-01-3031	Polymer Materials	WS
	11-01-3030	Polymer Processing	SS
	11-01-2023	Porous ceramics for energy-related applications	WS
	11-01-8411	Properties of Ferroelectric Materials	SS
	11-01-2019	Quantum Materials: Theory, Numerics, and Applications	SS
	11-01-7060	Scanning Probe Microscopy in Materials Science	SS
	11-01-9062	Scanning Transmission Electron Microscopy for Materials Science	SS
	11-01-8162	Semiconductor Interfaces	WS
	11-01-8211	Seminar Metals	SS
	11-01-4055	Seminar Research Topics in Materials Science	WS & SS
	11-01-2002	Spintronics	SS
	11-01-2021	Technology of Nanoobjects	SS
	11-01-3577	Thermodynamics and Kinetics of Defects	SS
	11-02-6330	Transmission Electron Microscopy (TEM)	WS
	11-01-2018	Tunable properties in nanomaterials	SS

Module Description

<table>
<tr><td colspan="7">Module name

Master Thesis</td></tr>
<tr><td colspan="2">Module no.
11-01-MT15</td><td>Credit Points
30 CP</td><td>Workload
900 h</td><td>Self-study
900 h</td><td>Duration
1 Semester</td><td>Frequency
Every semester</td></tr>
<tr><td colspan="4">Language of Instruction
German and English</td><td colspan="3">Person responsible for the Module</td></tr>
<tr><td rowspan="2">1</td><td colspan="6">Courses of the Module</td></tr>
<tr><td>Course no.</td><td colspan="2">Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td>2</td><td colspan="6">Study Content
• Familiarization with the subject and setup of a work schedule.
• Experimental and/or theoretical work on a scientific subject.
• Documentation of the results by authoring the Master thesis.
• Presentation of the results in a talk with subsequent scientific discussion.
• Public presentation of the results of the Master thesis with subsequent scientific discussion.</td></tr>
<tr><td>3</td><td colspan="6">Learning Outcomes
The student knows the foundations about a current, usually research related question in materials science. He/she knows structure and composition of scientific publications. He/she is able to apply acquired knowledge and qualifications to specific scientific topics with newly acquired methods and means in order to independently work on scientific problems in a sufficient depth and breadth. He/she is able to autonomously create documentations and presentations about his/her research work and results.
The student is able to adequately present his/her results and to discuss and defend them in a public scientific environment.</td></tr>
<tr><td>4</td><td colspan="6">Requirements for Participation
Completion of
• an approved industrial internship
• 75 CP from compulsory and elective modules
• the Advanced Research Lab</td></tr>
<tr><td>5</td><td colspan="6">Form of Examination
Final Module Examination:

• Module Examination (Final Examination, Submission, Standard)</td></tr>
<tr><td>6</td><td colspan="6">Requirements on the Award of Credit Points
Master thesis and public defense with discussion have to be passed.</td></tr>
</table>

7	**Grading** Final Module Examination: • Module Examination (Final Examination, Submission, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** as announced by the advisor
10	**Comment** Cycle: A Master thesis may be started at any time. Advanced Research Lab and Master thesis are carried out at a research group of the Materials Science department. Upon formal request the examination committee may approve a Master thesis at another department or outside of TU Darmstadt. Nota bene: Only maximal one of Advanced Research Lab and Master thesis may be carried out externally. "Externally" means outside the research group of a university professor, where the university profesor needs not necessarily be a TU Darmstadt professor and the research group needs not necessarily be located at a university.

Module Description

Module name Research Lab I					
Module no. 11-01-4101	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Wolfgang Donner		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-4011-pr	Research Lab I	0	Practical / Lab / Internship	4

2	**Study Content** Experiments: • Barriers at a Semiconductor/Metal Interface • Thin Film Growth by PLD • Surface Characterization with AFM • X-Ray Fluorescence Analysis (XRF)

3	**Learning Outcomes** In experiments with partly open results, the candidate gets used to modern state-of-the-art scientific equipment in materials science. The experiments are performed using the equipment of the involved research groups, making sure that every student is exposed to scientific research groups. The students are able to plan and realize materials synthesis and characterization experiments self-reliantly. They are able to analyze the data with complex data analysis programs. They can discuss and interpret the results in a complex material context.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Submission, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** attestations for all experiments have to be obtained
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Submission, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** to be provided in the introduction to each experiment
10	**Comment** Cycle: each winter semester

Module Description

Module name Research Lab II					
Module no. 11-01-4102	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Wolfgang Donner		

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-4012-pr	Research Lab II	0	Practical / Lab / Internship	4

2	**Study Content** Experiments: • XRD: Thin Films • Characteristics of ferroelectric materials • Organic thin film transistors (TFT) • Dielectric response and optical materials properties • Kinetics of diffusion-dominated transitions: hardening of aluminum alloys
3	**Learning Outcomes** In experiments with partly open results, the candidate gets used to modern state-of-the-art scientific equipment in materials science. The experiments are performed using the equipment of the involved research groups, making sure that every student is exposed to scientific research groups. The students are able to plan and realize materials synthesis and characterization experiments self-reliantly. They are able to analyze the data with complex data analysis programs. They can discuss and interpret the results in a complex material context.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Submission, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** attestations for all experiments have to be obtained
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Submission, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** to be provided in the introduction to each experiment
10	**Comment**

	Cycle: each summer semester

Module Description

Module name					
Advanced Research Lab and Seminar					
Module no. 11-01-4103	**Credit Points** 15 CP	**Workload** 450 h	**Self-study** 450 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Wolfgang Donner		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
11-01-4008-se	Advanced Research Lab and Seminar	0	Seminar	0

2 Study Content

Each working group offers scientific tasks which are part of their research program. These tasks have no fixed solution, the solution has to be developed in an interplay between student and the involved members of the research group.
The students have to hand out a written report of their lab work and present a talk summarizing their work.

3 Learning Outcomes

The student is exposed to a controlled research activity within a real scientific working group. He gains the ability to understand a scientific problem from its different aspects, and how a limited research task is connected to more general and larger research objectives. The student gains experience to judge which individual type of research matches his/her individual interest and capabilities. As a result the student has the competence to choose a suited topic for the master thesis.
The students get acquainted to present their results in front of scientist which are working in the same field of research. The student learns to present in a clear and ordered way, understands how to use modern means of presentation such as animated images etc. The student gets used to defend his/her work against critical questions.

4 Requirements for Participation

none

5 Form of Examination

Course Examination:

	□• [11-01-4008-se] (Study Examination, Paper, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** passing of report and of oral talk
7	**Grading** Course Examination: □• [11-01-4008-se] (Study Examination, Paper, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** Provided according to the individual tasks. The student has to find the relevant literature as part of the task.
10	**Comment** Cycle: The Advanced Research Lab (ARL) may be started at any time. Shorter versions of this ARL module are offered for some double degree students: 11-01-4198 with 12 ECTS (workload 360h) for AMIR M2 and FAME M1 students 11-01-4197 with 8 ECTS (workload 240h) for FAME M1 students 11-01-4199 with 7 ECTS (workload 210h) for AMIS M1 students

Module Description

Module name					
Functional Materials					
Module no. 11-01-4104	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr.-Ing. Oliver Gutfleisch		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-1036-vl	Functional Materials	0	Lecture	4

2	**Study Content** Functional Materials and specific devices: • Conductivity in metals, • Semiconductors, • Thermoelectricity, • Organic semiconductors,

	• Ionic conductors, • Dielectric and ferroelectric materials, • Introduction to magnetism and magnetic materials, • Magnetic materials and their applications (permanent and soft magnets), • Magnetocaloric materials, • Metal Hydrides, • Superconductors.
3	**Learning Outcomes** Gaining knowledge of the most important principles in the before mentioned material classes. Focusing not only on the physical principles but also materials synthesis and application of the most important functional materials. Furthermore applications of these material classes will be discussed. The students will be able to develop and characterise simple devices constructed from the above mentioned materials.
4	**Requirements for Participation** recommended: good knowledge of Materials Science I-VI (Bachelor course), knowledge of basic solid state physics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Mandatory Course Materials Science. In order to avoid doubling of curricular elements, students who graduated from TU Darmstadt with a Bachelor in Materials Science within the study regulations from 2008 are NOT allowed to take this module for credit and must instead take more Elective Courses Materials Science to compensate for the missing 6 CP.
9	**Literature** 1. K.Nitzsche, H.-J.Ullrich, „Funktionswerkstoffe der Elektrotechnik und Elektronik“, Deutscher Verlag für Grundstoffindustrie, Leipzig (1993). 2. O. Kasap, “Principles of Electronic Materials and Devices”, Mcgraw-Hill Publ. Comp. (2005). 3. Rolf E.Hummel, „Electronic properties of materials“, Springer Verlag (1993). 4. J.C.Anderson et al., „Materials Science“, Chapman & Hall Verlag (1990). 5. C.Kittel, „Einführung in die Festkörperphysik“, 14. Auflage, Oldenburg Verlag, München (2006). 6. H.Ibach, H.Lüth, "Festkörperphysik", 6. Auflage, Springer Verlag, Berlin (2002).

	7. E.A.Silinsh, V.Capek, "Organic molecular crystals" , AIP Press (1994). 8. W.Brütting, "Physics of organic semiconductors", Wiley- VCH (2005). 9. W.Buckel, R.Kleiner „Supraleitung“, 6. Auflage, Wiley-VCH Verlagsgesellschaft (2004). 10. J. M. D. Coey, “Magnetism and Magnetic Materials”, Cambridge University Press (2010). 11. B. D. Cullity, “Introduction to Magnetic Materials”, Wiley-IEEE Press (2008). 12. O’Handley, “Modern magnetic materials: principles and applications”, Wiley & Sons (2000) 13. Darren P. Broom, “Hydrogen Storage Materials: The characterisation of Their Storage Properties (Green Energy and Technology)”, Springer (2011).
10	**Comment** Cycle: each winter semester

Module Description

Module name

Surfaces and Interfaces

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-4105	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. Wolfram Jaegermann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7922-vl	Surfaces and Interfaces	0	Lecture	3

2 Study Content

- surfaces of solids: thermodynamics of surface formation, structure of surfaces, electronic structure of surface and surface potentials
- kinetics of surface reactions: physisorption and chemisorption, surface diffusion, surface reactions and catalysis
- internal surfaces: structural models, thermodynamics of internal surfaces, epitaxy and growth modes
- solid/electrolyte interfaces: thermodynamics and electrochemical double layers, thermodynamics of electrochemical reactions, kinetics of electrochemical reactions, corrosion and corrosion modes

3 Learning Outcomes

The student is able to understand and treat the specific effects of surfaces and interfaces in materials science, he/she differentiates between thermodynamically and kinetically

	determined properties, he/she knows the important terms and definitions and related theoretical concepts used in surface/interface science and electrochemistry, he/she has reached a conceptual understanding how surfaces/interfaces affect the properties of presented devices, he/she will reach a materials science related understanding of electrochemical processes, he/she will be able to transfer this knowledge to any future envisaged problems and materials, the student has reached the competence to differentiate between bulk and surface effects in devices and to correlate them with material's properties, he/she is qualified to evaluate experimental and theoretical methods in his/her possible future research involving surface/interface effects and electrolyte interfaces, he/she will have the competence to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** recommended: elementary knowledge in physics, especially quantum mechanics and solid state physics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** 1. H. Lüth, "Surfaces and Interfaces of Solid Materials", Springer Verlag (1995) 2. K. Christmann, "Introduction to Surface Physical Chemistry", Steinkopff Verlag Darmstadt, Springer Verlag New York (1991) 3. H.D. Dörfler, "Grenzflächen und Kolloidchemie" VCH-Verlagsgesellschaft (1994) 4. Zangwill, "Physics at Surfaces", Cambridge University Press 5. E.S. Machlin, "Thermodynamics and Kinetics", Columbia University New York 6. M.Henzler, W.Göpel, "Oberflächenphysik des Festkörpers", Teubner Stuttgart (1991) 7. M.A. Herman, H. Sitter, "Molecular Beam Epitaxy", Springer-Verlag (2nd Ed.) 8. Carl H. Hamann, W. Vielstich "Elektrochemie", Wiley VCH, (3. Aufl.) 9. Helmut Kaesche, "Die Korrosion der Metalle", Springer-Verlag (3. Aufl.)
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Theoretical Methods in Materials Science					
Module no. 11-01-4106	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Karsten Albe		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9314-ue	Exercises Theoretical Methods in Materials Science	0	Exercise	1
11-01-9314-vl	Theoretical Methods in Materials Science	0	Lecture	3

2 Study Content

- Balance equations of mechanics and thermodynamics
- Free energy of non-uniform materials
- Fluctuations and stability
- Linear non-equilibrium thermodynamics
- Transition state theory and transport processes
- Statistical mechanics models for materials
- Quantum statistical mechanics
- Optimization techniques
- Partial differential equations in materials science
- Boundary value problems in materials science

3 Learning Outcomes

The student gains fundamental insights into the key concepts of non-equilibrium thermodynamics, continuum mechanics and (quantum) statistical mechanics relevant for materials science. He/she is able to identify and apply appropriate theoretical concepts for solving materials science problems related to properties and processing of materials. The students are acquainted to numerical methods and capable to solve boundary value problems, ordinary differential equations and transport equations. His/her knowledge allows him/her to follow advanced textbooks and scientific literature on theoretical methods in materials science.

4 Requirements for Participation

recommended: module „Quantum Mechanics for Materials Science” or module "Micromechanics for Materials Science"

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** 1. R.B. Balluffi, S.M. Allen, W. C. Carter, Kinetics of Materials, Wiley (2005) 2. P. Haupt, Continuum Mechanics and Theory of Material, Springer 3. JR. Acton, P.T. Squire, Solving Equations with Physical Understanding, Adam Hilger, Bristol (1985) 4. D. Kondepudi, I. Prigogine, Modern Thermodynamics: From heat engines to dissipative structures, Wiley (1998) 5. D. C. Wallace, Thermodynamics of Crystals, Dover (1998) 6. R.K. Pathria, Statistical Mechanics, Elevier Butterworth-Heinemann (2005) 7. Rob Philips, Crystals, Defects and Microstructures, Cambridge (2001)
10	**Comment** Cycle: each summer semester

Module Description

Module name Advanced Characterization Methods of Materials Science					
Module no. 11-01-4107	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Wolfgang Donner		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	11-01-9313-ue	Exercises Advanced Characterization Methods of Materials Science	0	Exercise	1
	11-01-9313-vl	Advanced Characterization Methods of Materials Science	0	Lecture	3

2	**Study Content** • Small Angle Scattering • Scattering from Amorphous Materials • Diffraction from Nanocrystals • Thin Film Diffraction • Photoelectron Spectroscopy • Spectral Photometry • Atomic Absorption Spectrometry • Optical Emission Spectrometry • X-ray Fluorescence Analysis • Neutron Activation Analysis • Proton-Induced X-Ray Emission • Rutherford Backscattering Spectrometry • Nuclear Reaction Analysis • Elastic Recoil Detection
3	**Learning Outcomes** The student knows the fundamentals of various methods of structural and elemental analysis, their advantages and disadvantages. He/she is able to select an appropriate technique for a given analytical problem. The course prepares the students for the practical courses, where they perform analytical experiments on their own. The methods presented in the course represent the state of the art in scattering and spectrometry; therefore the students will be able to critically judge the validity of experimental results in the scientific literature.
4	**Requirements for Participation** recommended: module „Quantum Mechanics for Materials Science“
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8	**Usability of the Module** M.Sc. Materials Science: compulsory module
9	**Literature** 1. Small Angle Scattering, Glatter & Kratky, ebook 2. Underneath the Bragg Peaks, Egami & Billinge, ebook 3. High Resolution X-ray Scattering, Holy, Pietsch, Baumbach, Springer 4. Structural and Chemical Analysis of Materials, Eberhard, Wiley 5. An Introduction to Surface Analysis by XPS and AES, Wolstenholme, ebook 6. Handbook of X-Ray Spectrometry, Marcel Dekker 7. Atomic and Nuclear Analytical Methods, Verma, Springer 8. Quantitative Chemical Analysis, Harris, Palgrave Mcmillan 9. Chemical Analysis, modern Instrumentation, Methods and Techniques, Rousseac
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Quantum Mechanics for Materials Science					
Module no. 11-01-4108	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Hongbin Zhang		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-4004-ue	Exercises Quantum Mechanics for Materials Science	0	Exercise	1
11-01-4004-vl	Quantum Mechanics for Materials Science	0	Lecture	2

2 Study Content

- Historical background
- Diffraction experiments
- Schrödinger equation and quantum mechanical properties
- The H- atom and H2-molecule, tunneling, harmonic oscillator
- LCAO model: from finite to infinite systems, the Bloch function
- Density of states in two and three dimensions, population density, Fermi statistics
- Bandgaps and their origin
- Transport equation of electrons in external fields
- Theory of free electrons

3	**Learning Outcomes** The successful students are able to recognize basic quantum mechanical phenomena. The students are able to derive and calculate simple quantum mechanical problems and are able to use them in daily problems. The students will be able to understand the nature of binding and the electronic structure of atoms, molecules and solids. The students are qualified to apply the theory to the evaluation of the electronic structure of atoms, molecules and solids and are able to describe charge transport in a quantum mechanical manner. The students have a first insight into modern research in quantum mechanics and their knowledge allows them to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** recommended: Bachelor modules “Physical Chemistry I” and “Materials Science VI & VII”
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: choice of this module or 11-01-4109 Micromechanics for Materials Science
9	**Literature** 1. Ch. Kittel: Introduction into solid state physics, John Wiley and Sons (1996) 2. H. Ibach, H. Lüth: Solid state physics, Springer Verlag (2002) 3. A. Sutton: Electronic structure of materias, Clarendon Press (1993) 4. P.W. Atkins, R.S.Friedman: Molecular Quantum Mechanics, Oxford University Press (2000) 5. R. Feynman: The Feynman lectures Vol. III, Addision-Wesley Publishing Company (1989). 6. Franz Schwabl, Advanced Quantum Mechanics, Springer Verlag (2008)
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Micromechanics for Materials Science					
Module no. 11-01-4109	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Ph. D. Bai-Xiang Xu		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7050-ue	Exercises in Micromechanics for Materials Science	0	Exercise	1
11-01-7050-vl	Micromechanics for Materials Science	0	Lecture	2

2 Study Content

This lecture deals with fundamentals of micromechanics in the framework of elasticity and plasticity theory. Important topics include: Basics of elasticity, plasticity, viscoplasticity and crystal plasticity, Theory of configurational force (including J-Integral), Micro-macro transition and homogenization, and damage mechanics.

3 Learning Outcomes

The successful students can interpret the elastic and plastic behavior of a material using the continuum theory, and describe the stress situation around certain microstructure e.g. at crack tips and near defects. They can also apply the basic concept of homogenization to calculate the effective properties of heterogeneous material. They will have the competence to follow advanced textbooks and scientific literature on nonlinear continuum mechanics and composite mechanics.

4 Requirements for Participation

recommended: basics of mathematics and elastomechanics

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: choice of this module or 11-01-4108 Quantum Mechanics for Materials Science
9	**Literature** 1. Ch. Kittel: Introduction into solid state physics, John Wiley and Sons (1996) 2. H. Ibach, H. Lüth: Solid state physics, Springer Verlag (2002) 3. A. Sutton: Electronic structure of materias, Clarendon Press (1993) 4. P.W. Atkins, R.S.Friedman: Molecular Quantum Mechanics, Oxford University Press (2000) 5. R. Feynman: The Feynman lectures Vol. III, Addision-Wesley Publishing Company (1989). 6. Franz Schwabl, Advanced Quantum Mechanics, Springer Verlag (2008)
10	**Comment** Cycle: each winter semester

Module Description

Module name Concepts in Materials Physics					
Module no. 11-01-2009	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Robert Stark		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2009-ue	Exercise: Concepts in Materials Physics	0	Exercise	1
11-01-2009-vl	Concepts in Materials Physics	0	Lecture	2

2 Study Content

Description the crystalline state of solids, atomic cohesion and crystal bonding, lattice, reciprocal lattice, x-ray diffraction and determination of the crystal structure, spectroscopy, lattice vibrations (phonons), thermal properties of solids, (quasi) free electron theory of metals, electronic structure, semiconductors, magnetism.

3	**Learning Outcomes** The student is able to describe a crystal as a lattice with a pattern and can explain x-ray diffraction patterns using the concept of the reciprocal lattice. He/She has gained an understanding of diffraction of electromagnetic waves, electron waves or collective excitations in a lattice. In particular the students are able to explain fundamental material properties in the appropriate pictures of quasi-particles and collective excitations. He/She has gained an understanding for the relation between transport properties, crystal structure, and electronic structure.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Compulsory module for students with a respective obligation. Students without such an obligation may take this module for credit only if they are NOT Bachelor graduates in Materials Science from TU Darmstadt.
9	**Literature** 1. R.B. Balluffi, S.M. Allen, W. C. Carter, Kinetics of Materials, Wiley (2005) 2. P. Haupt, Continuum Mechanics and Theory of Material, Springer 3. JR. Acton, P.T. Squire, Solving Equations with Physical Understanding, Adam Hilger, Bristol (1985) 4. D. Kondepudi, I. Prigogine, Modern Thermodynamics: From heat engines to dissipative structures, Wiley (1998) 5. D. C. Wallace, Thermodynamics of Crystals, Dover (1998) 6. R.K. Pathria, Statistical Mechanics, Elevier Butterworth-Heinemann (2005) 7. Rob Philips, Crystals, Defects and Microstructures, Cambridge (2001)
10	**Comment** Cycle: each winter semester. This module is not allowed as an elective course for graduates with a Bachelor in Materials Science from TU Darmstadt.

Module Description

Module name					
Advanced Light Microscopy					
Module no. 11-01-3029	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Robert Stark		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-3029-vl	Advanced Light Microscopy	0	Lecture	2

2 Study Content

The lecture covers topics in materials optics and gives an overview on how to use light in order to characterize materials. Conventional light microscopy methods are discussed with respect to their applications in (bio)materials science. Theoretical and practical aspects of modern super-resolution techniques are discussed.

1. Electromagnetic Waves at interfaces (Electromagnetic waves; Reflection and transmission: External reflection, Internal reflection, Frustrated total internal reflection (FTIR), Total internal reflection microscopy)
2. Electromagnetic properties of materials (The dielectric response; The Lorentz model of dielectrics; Drude‘s model for metals)
3. Birefringence (Optical Anisotropy; Anisotropic dispersion; Uniaxial Materials; Biaxial and other Materials)
4. Optical Activity, Electro Optics, and Magneto Optics (Optical activity; Electro-Optics; Magneto-Optic Effects)
5. Paraxial Optics: Thin Lenses, Thick Lenses, and ABCD Formalism (Curved mirrors; Thin Lenses; Thick Lenses; ABCD Matrices)
6. Optical aberrations and stops (Aberrations; Stops in Optical Systems; Optical devices)
7. Widefield Microscopy (The compound microscope; Resolution; Bright field microscopy; Dark field; Phase contrast; Differential Interference Contrast (DIC); Polarisation microscopy; Fluorescence microscopy)
8. Confocal Microscopy (The confocal principle; Scanning; The pinhole; Airy Scanning)
9. Super resolution microscopy – Beating Abbe‘s limit (3-D methods based on nonlinear optical phenomena, Common ideas, 2-photon excitation, Second harmonic generation; 4Pi-microscopy: Looking at the specimen from both sides; Structured illumination microscopy (SIM); Stimulated emission depletion (STED) microscopy; Stochastic optical reconstruction microscopy (STORM) or (fluorescence) photoactivation localization microscopy ((F)PALM))
10. Scanning nearfield optical microscopy (SNOM/NSOM) (The basic idea; Near field probes; Aperture SNOM; Scattering SNOM (s-SNOM))
11. Raman Microscopy (Raman Scattering; Raman microscopy; Symmetry of moleculatr vibrations; Symmetry of phonon modes)

	If time permits: 12. Light Sources, Lasers and Coherence
3	**Learning Outcomes** Students understand the interaction of electromagnetic waves with ordered materials, in particular with non-isotropic materials in terms of polarization, electro- and magneto optics, optical activity and photon-phonon interaction. The student is able to design a simple optical device in order to perform optical measurements on materials, in terms of defining position and quality of lenses, filters, stops, mirrors, light sources and detectors. The student is able to handle a light microscope in order to achieve a homogenously exposed image with high contrast of typical specimen in (bio)materials science. The student understands the reason for Abbe's resolution limit and knows how this limitation can be overcome in specific cases. The student is able to choose the appropriate super-resolution technique for a specific problem in (bio)materials science.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Eugene Hecht, Optics, Pearson, 5th Ed 2017 2. John Ferraro et al., Introductory Raman Spectroscopy, Academic Press, 2nd Ed. 2003 3. Jerome Mertz, Introduction to Optical Microscopy, Roberts and Co., 2009 4. Jörg Haus, Optische Mikroskopie: Funktionsweise und Kontrastierverfahren, Wiley-VCH 2014
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Ceramic Materials: Syntheses and Properties. Part I					
Module no. 11-01-8191	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Ralf Riedel		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8191-vl	Ceramic Materials: Syntheses and Properties. Part I	0	Lecture	2

2 Study Content

- Introduction: Definitions; Classes of Ceramic Materials; Applications
- Engineering Ceramics: Preparation, Microstructure, Properties
- Thermodynamics (Phase Diagrams, Interface Energies); Kinetics
- Synthesis Techniques of Ceramic Powders
- Carbides: Silicon Carbide (SiC), Boron Carbide (B_4C), Titanium Carbide (TiC)
- Nitrides: Silicon Nitride (Si_3N_4), Aluminum Nitride (AlN), Boron Nitride (BN), Titanium Nitride (TiN)
- Borides, Silicides
- Oxides: Aluminum Oxide (Al_2O_3), Zirkonium Dioxide, Multicomponent Oxides

3 Learning Outcomes

The student has gained an overview on and remembers different synthesis techniques for ceramic materials. Furthermore, he/she has gained the competence to evaluate the (micro)structure-properties relationship for ceramic materials. He/she is able to correlate different classes of ceramic materials with specific properties and applications. The student has the competence to evaluate experimental and theoretical methods for goal-oriented research in the area of ceramics. The student has a first insight in modern preparative techniques for ceramic materials and a beginner's competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Allgemeine Lehrbücher für anorganische Chemie 2. U. Schubert, N. Hüsing, „Synthesis of Inorganic Materials“, Wiley-VCH, Weinheim, 2000 3. W. Büchner, R. Schliebs, G. Winter, K. H. Büchel, „Industrielle Anorganische Chemie“, Wiley-VCH, Weinheim, 1986 4. M. W. Barsoum, „Fundamentals of Ceramics“, Institute of Physics Publishing, Bristol and Philadelphia, 2003 5. Salmang, Scholze, „Keramik“ Teil 1 und 2, Springer Verlag, Berlin 1982; ISBN 3-540-10987-0 6. W. D. Kingery, H. K. Bowen, D. R. Uhlmann, “Introduction to Ceramics”, John Wiley and Sons, New York 1976; ISBN 0-471-47860-1 7. W. Schatt, „Einführung in die Werkstoffwissenschaft“, VEB Deutscher Verlag, Leipzig 1972; ISBN 3-342-00190-9 8. H. Scholze, Glas, Natur, „Struktur und Eigenschaften“, Springer Verlag, Berlin 1988, ISBN 3-540-18977-7 9. D. Segal, “Chemical Synthesis of Advanced Ceramic Materials”, Series “Chemistry of Solid State Materials“ 1, Cambridge University Press, Cambridge 1989; ISBN 0-521-42418-6
10	**Comment** Cycle: each summer semester

Module Description

Module name Ceramic Materials: Syntheses and Properties. Part II					
Module no. 11-01-7342	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. Emanuel Ionescu		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact**

				Teaching	Hours per Week
	11-01-7342-vl	Synthesis and Properties of Ceramic Materials II	0	Lecture	2

2	**Study Content** • Powder Processing • Shaping Techniques • Pyrolysis Processes • Sintering • Silicon carbide, silicon nitride, silicon oxycarbides, silicon carbonitrides
3	**Learning Outcomes** The student has gained practical experience with and remembers different processing techniques for ceramic materials. Furthermore, he/she has gained the competence to correlate the relationship between (micro)structure/phase composition of ceramics and their property profiles. The student gets acquainted with modern processing techniques for ceramic materials and is able to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. W. D. Kingery, Introduction to Ceramics, Wiley ,1976. 2. J. R. Reed, Introduction to the Principles of Ceramic Processing, Wiley, 1987. 3. U. Schubert, N. Hüsing, Synthesis of Inorganic Materials, Wiley-VCH, 2000. 4. P. Colombo, G. D. Soraru, R. Riedel, H.-J. Kleebe, Polymer-Derived Ceramics: from Nanostructure to Applications, DEStech Publications Inc., 2009. 5. R. Riedel, I.-W. Chen, Ceramics Science and Technology, vols. 1-4, Wiley-VCH, 2008-2014. 6. N. Bansal, A. R. Boccaccini, Ceramics and Composites Processing Methods, Wiley, 2012.

10	**Comment** Cycle: each winter semester

Module Description

Module name					
Characterization Methods in Materials Science: Neutrons and Synchrotron					
Module no. 11-01-9811	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Wolfgang Donner		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9811-vl	Characterization Methods in Materials Science II - Neutrons and Synchrotron	0	Lecture	2

2 Study Content

- Synchrotron and Neutron Sources
- Neutron Reflectivity
- Crystal Truncation Rod Diffraction
- Diffuse Scattering
- Inelastic Scattering
- Quasi-elastic Scattering
- Coherent Diffraction and Reconstruction
- Selected topics from current research

3 Learning Outcomes

The students learn about the technology and possibilities of large research facilities. They are able to relate the specific advantages of Neutron and Synchrotron sources over conventional lab-based radiation sources to modern analytical methods. The course enables the students to associate specific problems in Materials Science to analytical techniques that are available at large scale facilities. The students are qualified to design specific experiments at Neutron and Synchrotron sources and evaluate the resulting data. They acquired a competence to critically evaluate the outcome of large scale experiments and to comment on results presented in the literature.

4 Requirements for Participation

none

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Elements of Modern X-ray Physics, Als-Nielsen & McMorrow 2. Diffuse X-ray Scattering and Models of Disorder, Welberry 3. Diffuse X-ray Scattering from Crystalline Materials, Nield & Keen
10	**Comment** Cycle: as needed/on request

Module Description

Module name

Chemical Sensors: Basics and Applications

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-8241	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. Ralf Riedel

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8241-vl	Chemical Sensors: Basics and Applications	0	Lecture	2

2 Study Content

- Chemical and Biological sensors
- Materials and Methods in Chemical sensor manufacturing.

	• Enzymes and Enzymatic sensors. • Nucleic Acids in Chemical Sensors. • Nanomaterial application in chemical sensors. • Thermochemical sensors • Optical sensors • Chemical sensors based on semiconductor electronic devices • Gas sensors • Potentiometric sensors
3	**Learning Outcomes** The students have an overview of the different types of chemical sensors. They are able to describe the operation principles for chemical sensors and give examples of their applications. They are able to decide which sensor is appropriate for a given problem/application.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. P. Gründler, Chemical Sensors: An Introduction for Scientists and Engineers/Chemische Sensoren. Eine Einführung für Naturwissenschaftler und Ingenieure, Springer, Berlin, 2004 (Deutsch)/2007 (English). 2. M. J. Madou, S. R. Morrison, Chemical Sensing with Solid State Devices, Academic Press, San Diego, 1989. 3. Chemical and Biochemical Sensors (Sensors: A Comprehensive Survey, Vol.2, Pt.1) (Eds.: W. Göpel, Jones, T.A., Kleitz, M., Lundström, J., Seiyama, T.), VCH, Weinheim, 1991.
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Computational Materials Science					
Module no. 11-01-7562	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Karsten Albe		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7562-ue	Exercise Computational Materials Science	0	Exercise	1
11-01-7562-vl	Computational Materials Science	0	Lecture	2

2 Study Content

- Introduction to Basic Concepts of Thermodynamics and Statistics
- Molecular Dynamics Method: Principles
- Equilibrium Thermodynamics and MD-Simulations
- Overview of Analytic Potentials
- Transport Processes and MD-Simulations
- Monte-Carlo Methods
- Kinetic Monte-Carlo Methods
- Bridging Time Scales: Accelerated Dynamics
- Foundations of Density Functional Theory
- Kohn-Sham Ansatz
- Functionals for Exchange and Correlation

Electronic Structure Calculations: PlaneWaves, LCAO, …

3 Learning Outcomes

The student knows fundamentals, possible applications and limitations of computational methods relevant in materials science. He/she has a basic understanding of the underlying numerical methods and algorithms and has gained practical experience with standard software packages like LAMMPS for molecular dynamics simulations. ABINIT for electronic structure calculations and software tools for data analysis (OVITO). He/she will have the competence to follow advanced textbooks and scientific literature on atomistic methods in materials science.

4 Requirements for Participation

recommended: modules “Quantum Mechanics for Materials Science” and “Theoretical Materials Science”

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. R.B. Balluffi, S.M. Allen, W. C. Carter, Kinetics of Materials, Wiley (2005) 2. P. Haupt, Continuum Mechanics and Theory of Material, Springer 3. JR. Acton, P.T. Squire, Solving Equations with Physical Understanding, Adam Hilger, Bristol (1985) 4. D. Kondepudi, I. Prigogine, Modern Thermodynamics: From heat engines to dissipative structures, Wiley (1998) 5. D. C. Wallace, Thermodynamics of Crystals, Dover (1998) 6. R.K. Pathria, Statistical Mechanics, Elevier Butterworth-Heinemann (2005) 7. Rob Philips, Crystals, Defects and Microstructures, Cambridge (2001)
10	**Comment** Cycle: each winter semester

Module Description

Module name **Computer Models of Solid Materials**					
Module no. 11-01-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. rer. nat. Elaheh Ghorbani		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	11-01-2020-vl	Computer Models of Solid Materials	0	Lecture	2

2	**Study Content** This course involves hands-on sessions focusing on the following essential topics in solid state materials through working with interactive models: - Crystal structures of solids - Lattice dynamics - Free electron gas model (FEG) - Energy bands of electrons in periodic potentials - Electronic transport in partially filled bands - Semiconductor crystals - Ising-Model and ferromagnetism - Dislocations
3	**Learning Outcomes** Through numerous qualitative and quantitative exercises, the students have gained a visual picture of condensed systems' behavior. Moreover, via active participation the students have acquired the ability to develop the conceptual framework for each topic, which leads them to gain critical ideas of solid state phenomena and to deliver proper numerical and perceptual analyses of physical systems.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. R. H. Silsbee, J. Dräger: "Simulations for Solid State Physics", Cambridge university press, Cambridge (1997) 2. C. Kittel: "Introduction to Solid State Physics", Wiley, New York (2005) 3. M. P. Marder: "Condensed Matter Physics", Wiley, New York (2000) 4. J. D. Patterson, B. C. Bailey: "Solid-State Physics - Introduction to the Theory", Springer (2007)

10	**Comment** Cycle: each summer semester

Module Description

Module name Course Processing of Conventional and Polymer Derived Silicon Ceramics					
Module no. 11-01-9902	**Credit Points** 2 CP	**Workload** 60 h	**Self-study** 45 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. Emanuel Ionescu		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9902-ku	Course Processing of Conventional and Polymer Derived Silicon Ceramics	0	Course	1

2 Study Content

- Powder Processing
- Shaping Techniques
- Pyrolysis Processes
- Sintering
- Silicon carbide, silicon nitride, silicon oxycarbides, silicon carbonitrides

3 Learning Outcomes

The student has gained practical experience with and remembers different processing techniques for ceramic materials. Furthermore, he/she has gained the competence to correlate the relationship between (micro)structure/phase composition of ceramics and their property profiles. The student gets acquainted with modern processing techniques for ceramic materials and is able to follow advanced textbooks and scientific literature.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

	passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. W. D. Kingery, Introduction to Ceramics, Wiley ,1976. 2. J. R. Reed, Introduction to the Principles of Ceramic Processing, Wiley, 1987. 3. U. Schubert, N. Hüsing, Synthesis of Inorganic Materials, Wiley-VCH, 2000. 4. P. Colombo, G. D. Soraru, R. Riedel, H.-J. Kleebe, Polymer-Derived Ceramics: from Nanostructure to Applications, DEStech Publications Inc., 2009. 5. R. Riedel, I.-W. Chen, Ceramics Science and Technology, vols. 1-4, Wiley-VCH, 2008-2014. 6. N. Bansal, A. R. Boccaccini, Ceramics and Composites Processing Methods, Wiley, 2012.
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Density Functional Theory: A Practical Introduction					
Module no. 11-01-8291	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Karsten Albe		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8291-ue	Exercises Density Functional Theory: A Practical Introduction	0	Exercise	1
11-01-8291-vl	Density Functional Theory: A Practical Introduction	0	Lecture	2

2 Study Content

Density functional theory (DFT) is one of the most frequently used computational tools for

	studying and predicting the properties of isolated molecules, bulk solids, and material interfaces, including surfaces. In this lecture the basic theoretical concepts underlying DFT calculations are introduced. Practical applications of DFT, focusing on planewave DFT, are discussed and hands-on training is provided using the open-source code ABINIT. The course is a practical introduction for students of materials science, physics and chemistry who want to use DFT in their work. • Short repetition of Quantum Mechanics (infinitely deep well, harmonic oscillator, H atom, Hartree-Fock approximation for interacting systems) • Basic concepts in DFT (Hohenberg-Kohn theorems, Kohn-Sham ansatz, local-density approximation) • Functioning of DFT planewave pseudopotential codes • Tools for electronic-structure analysis (density, density of states, Bader charge analysis, band structure) • Calculating bulk properties • Calculating defect (free) energies (surfaces, interfaces, point defects) • Calculating kinetic energy barriers (nudged-elastic-band method) • Modeling complex structure: ab initio molecular dynamics, simulated annealing, basin hopping and other structure search techniques. • Density-functional perturbation theory: application to phonon band-structures • Improved band-structure methods: LDA+U, hybrid functionals and the GW method.
3	**Learning Outcomes** After successfully completing this course, the student will be in the position to independently run DFT calculations using the ABINIT code and the PYTHON based Atomic Simulation Environment package. Specifically he/she will learn how to compute bulk elastic properties, surface/interface/defect (free) energies, electron and phonon band-structures and transition barriers for chemical reactions. In addition, the student will learn how to use density-of-states, electron densities and Kohn-Sham orbitals as tools for electronic-structure analysis. Finally, he/she will be introduced to basic concepts of DFT (Hohenberg-Kohn theorems, Kohn-Sham ansatz, local density approximation of the exchange-correlation functional) and of the functioning of planewave-pseudopotential codes.
4	**Requirements for Participation** recommended: background in materials science, physics, or chemistry on the bachelor level
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight:

	100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. R.B. Balluffi, S.M. Allen, W. C. Carter, Kinetics of Materials, Wiley (2005) 2. P. Haupt, Continuum Mechanics and Theory of Material, Springer 3. JR. Acton, P.T. Squire, Solving Equations with Physical Understanding, Adam Hilger, Bristol (1985) 4. D. Kondepudi, I. Prigogine, Modern Thermodynamics: From heat engines to dissipative structures, Wiley (1998) 5. D. C. Wallace, Thermodynamics of Crystals, Dover (1998) 6. R.K. Pathria, Statistical Mechanics, Elevier Butterworth-Heinemann (2005) 7. Rob Philips, Crystals, Defects and Microstructures, Cambridge (2001)
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Dislocations in Ceramics					
Module no. 11-01-2025	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** M.Sc. Lukas Winfred Porz		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-2025-vl	Dislocations in Ceramics	0	Lecture	2
2	**Study Content** Dislocations in ceramics show a surprising potential to alter functional properties of ceramics. At the same time, their mechanics is a complex topic and often dislocations are simply believed to not exist in or be irrelevant for ceramics. This lecture will review the difference in dislocation behavior in ceramics and metals requiring a completely different perspective. Furthermore, characterization techniques and a range of functional applications are presented. Four blocks will be covered: 1) Basics of dislocations in ceramics: Slip systems, fundamental motion, specialties of dislocations in ionic crystals, typical features of dislocations, interaction of dislocations, … 2) Characterization techniques: TEM, ECCI, EBSD, x-ray diffraction, etch-pits, …				

	3) Dislocation mechanics in ceramics: Room-temperature plasticity, separation of: nucleation, motion and multiplication, thermally activated motion, plasticity of polycrystalline ceramics. 4) Functional properties: Core charge and compensating space charge, electrical conductivity, diffusion, thermal conductivity, optical properties, catalytic activity, …
3	**Learning Outcomes** The students will be introduced to both the functional and mechanical the role of dislocations in ceramics. Their strain field, core charge and compensating space charge allow to alter functional properties ranging from conductivity over the band gap to catalytic activity. The 1-dimensional nature adds geometrical complexity but also design opportunities. Surprisingly many ceramics (single crystals) are ductile at room temperature and even polycrystals can be deformed at elevated temperature. Yet the mechanical behavior requires a different perspective than plasticity in metals. This course ais to prepare students to independently navigate the research field of dislocations in ceramics.
4	**Requirements for Participation** Resommended: Bachelor modules "Materialwissenschaft III: (Defects in crystalline solids)" and "Materialwissenschaft IV: (Mechanical behavior of Materials)"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1.Gottstein, G., Materialwissenschaft und Wekstofftechnik, Physikalische Grundlagen. 4th edition ed.; Spinger: 2014. 2.Hull, D.; Bacon, D. J., Introduction to Dislocations, Fifth Edition. Elsevier: 2011. 3.Rösler, J.; Haders, H.; Bäker, M., Mechanical Behavior of Engineering Materials. Springer: 2019. 4.Anderson, P. M.; Hirth, J. P.; Lothe, J., Theory of Dislocations. Third edition ed.; Cambridge University Press: New York, 2017. 5. Messerschmidt, U., Dislocation Dynamics during Plastic Deformation. Springer: New York, NY, USA, 2010; Vol. 129. 6.Gilman, J. J.; Johnston, W. G., Dislocations in Lithium Fluoride Crystals. Solid State Phys

	1962, 13, 147-222. 7.Whitworth, R. W., Charged Dislocations in Ionic-Crystals. Advances in Physics 1975, 24, (2), 203-304.
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Electrochemistry for Energy Applications I: Fundamentals					
Module no. 11-01-7300	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Wolfram Jaegermann		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-7300-vl	Electrochemistry for Energy Applications I: Fundamentals	0	Lecture	2
2	**Study Content** • Electrochemical Thermodynamics • Electrochemical Kinetics • Electrochemical Methods • Fuel cells • Electrolysis				
3	**Learning Outcomes** The student will be introduced to the main concepts of heterogeneous electrochemistry (electrodics), basic electrochemical methods and main materials science questions related to the use and application of electrochemical converter devices. He/she will learn to evaluate experimental and theoretical results obtained with different electrochemical, surface science and theoretical techniques, and obtain a first insight in modern electrodics applied for continuing experimental work in this field. Moreover, he/she obtains basic competence to follow advanced textbooks and scientific literature.				
4	**Requirements for Participation** recommended: modules “Surfaces and Interfaces” and “Quantum Mechanics for Materials Science”				

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. G. Wedler; Lehrbuch der Physikalischen Chemie 2. P.W. Atkins; Physikalische Chemie (Physical Chemistry) 3. C.H. Hamann, W. Vielstich; Elektrochemie (Electrochemistry) 4. W. Schmickler; Grundlagen der Elektrochemie 5. W. Vielstich, A. Lamm, H. Gasteiger (eds); Handbook of Fuel Cells: Fundamentals, Technology, Application 6. G. Hoogers (ed.); Fuel Cell Technology Handbook
10	**Comment** Cycle: each summer semester

Module Description

Module name Electrochemistry for Energy Applications II					
Module no. 11-01-7301	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Wolfram Jaegermann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7301-vl	Electrochemistry for Energy Applications II	0	Lecture	2

2	**Study Content** • Solid State Ionics • Battery Fundamentals • Li-Ion Batteries • Semiconductor Electrochemistry • Electrochemical Solar Cell • Photocatalysis • Photoelectrochemical Hydrogen Production
3	**Learning Outcomes** The student will be introduced to the main concepts of heterogeneous electrochemistry (electrodics), solid state ionics and main materials science questions related to the use and application of electrochemical storage and converter devices. He/she will learn to combine electrochemical concepts and solid state concepts for dealing with energy devices and to evaluate experimental and theoretical results obtained with different electrochemical, surface science and theoretical techniques, and obtain a first insight in modern electrodics applied for continuing experimental work in this field. Moreover, he/she obtains basic competence to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** recommended: modules “Surfaces and Interfaces”, “Quantum Mechanics for Materials Science” and “Electrochemistry in Energy Applications I: Converter Devices”
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. G. Wedler; Lehrbuch der Physikalischen Chemie 2. C.H. Hamann, W. Vielstich; Elektrochemie (Electrochemistry) 3. J. Maier, Physical Chemistry of Ionic Materials 4. Thomas B. Reddy, David Linden, Handbook of batteries 5. Robert A. Huggins , Advanced Batteries, Materials Science Aspects 6. M. Wakihara, O. Yamamoto (eds.), Lithium Ion Batteries, Fundamentals and Performance 7. R. Memming; Semiconductor Electrochemistry 8. C.A. Grimes, O.K. Varghese, S. Ranjan; Light, Water, Hydrogen

10	**Comment** Cycle: each winter semester

Module Description

Module name

Electron Crystallography I

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-02-9052	3 CP	90 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Dr. rer. nat. Ute Kolb

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-02-9052-vu	Electron Crystallography I	0	Vorlesung und Übung	2

2 Study Content

- Basic concepts in crystallography
- Diffraction theory (kinematic/dynamic)
- Electron diffraction methods (parallel/convergent, electron beam precession)
- Tomography (direct/reciprocal)
- Phase problem and experimental/statistic solutions
- HRTEM (simulation of images and diffraction), holography
- Strategies for structure solution (direct methods, simulated annealing, charge flipping)
- Structure refinement, kinematic/dynamic

3 Learning Outcomes

This lecture covers in the beginning basic topics of crystallography and diffraction theory. It discusses the major electron diffraction methods, as well as real space imaging (HRTEM), necessary for the structural characterization of nanoscale materials. A central topic is the applicability of the different methods to materials with diverse degree of order. In addition it will be shown how other methods for structural characterization like X-ray- or neutron scattering or NMR can be combined with electron diffraction.

4 Requirements for Participation

recommended: module “Introduction to Scanning Electron Microscopy”

5 Form of Examination

Final Module Examination:

	□• Module Examination (Technical Examination, optional, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: □• Module Examination (Technical Examination, optional, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Transmission Electron Microscopy, D.B. Williams and C.B. Carter, (2nd Ed.) Springer Verlag (2009) 2. Electron Diffraction in the Electron Microscope, J.W. Edington, Macmillan (1975) 3. Electron Microdiffraction, J. C. H. Spence and J. M. Zuo, Springer Verlag, Berlin (1992) 4. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, R. Egerton, Springer Verlag (2005) 5. Optik, E. Hecht, Oldenburg Verlag, 3. Auflage (2001) 6. Fundamentals of Crystals, B.K. Vainshtein, Springer-Verlag, 2. Auflage (1994) 7. Diffraction Physics, J. M. Cowley, North-Holland (1975) 8. Kristallographie, W. Borchardt-Ott, Springer-Verlag, 5. Auflage (1997)
10	**Comment**

Module Description

Module name Electron Crystallography II					
Module no. 11-02-9053	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Dr. rer. nat. Ute Kolb		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-02-9053-vu	Electron Crystallography II	0	Vorlesung und Übung	2

2	**Study Content** • Coupling with other methods (X-ray powder diffraction, NMR, Spectroscopy, EXAFS, EXELFS) • Special crystallographic features(super structure/incommensurate compunds) • Handling of beam sensitive material • Diffraction on defects and description/refinement (DISCUS) • Electron powder diffraction and pair distribution functions (PDF) • Phase analysis using electron diffraction • precession electron diffraction (PED) • convergent beam electron diffraction (CBED) • ptychography • diffractive imaging
3	**Learning Outcomes** In this lecture basic electron microscopic methods for structural characterization will be combined with further methods for structure analysis (X-ray diffraction, neutron diffraction, NMR). In addition new special electron crystallographic techniques will be presented. With this tool box a broad range of methods for structure analysis of nano scaled material is provided supporting the understanding of materials physical properties.
4	**Requirements for Participation** Introduction to Transmission Electron Microscopy recommended
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, optional, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, optional, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Transmission Electron Microscopy, D.B. Williams and C.B. Carter, (2nd Ed.) Springer Verlag (2009) 2. Electron Diffraction in the Electron Microscope, J.W. Edington, Macmillan (1975) 3. Electron Microdiffraction, J. C. H. Spence and J. M. Zuo, Springer Verlag, Berlin (1992) 4. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, R. Egerton, Springer Verlag (2005) 5. Optik, E. Hecht, Oldenburg Verlag, 3. Auflage (2001) 6. Fundamentals of Crystals, B.K. Vainshtein, Springer-Verlag, 2. Auflage (1994) 7. Diffraction Physics, J. M. Cowley, North-Holland (1975) 8. Kristallographie, W. Borchardt-Ott, Springer-Verlag, 5. Auflage (1997)

10	**Comment**

Module Description

Module name					
Engineering Microstructures					
Module no. 11-01-8131	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Apl. Prof. Dr.-Ing. Clemens Müller		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
11-01-8131-vl	Engineering Microstructures - Processing, Characterization and Application	0	Lecture	1

2 Study Content

- Introduction (dislocations, subgrain structures, grain boundaries, phase boundaries)
- Microstructural analysis (microscopy and diffraction methods)
- Correlation between microstructure and mechanical properties
- Thermo-mechanical treatment (theory and processing)
- Recovery, recrystallization and grain growth
- Severe plastic deformation
- Microstructures for structural applications

3 Learning Outcomes

The student gains an overview of the variety of methods for microstructural engineering of metals and alloys including their thermodynamic principles and applications. The student remembers the potential and limits of state-of-the-art methods for microstructural analysis and is able to assess the most qualified method(s) for specific issues. He/she is qualified to evaluate experimental and theoretical methods for goal-oriented research in the area microstructural engineering by annealing, thermo-mechanical treatment or severe plastic deformation. The student has a beginner's competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

recommended: Bachelor modules "Materials Science III: Real Crystals and their Properties" and "Materials Science IV: Mechanical Properties"

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. R.W. Cahn, P. Haasen: Physical Metallurgy, Elsevier Science B.V. (1996) 2. F.J. Humphreys, M. Hatherly: Recrystallization and Related Annealing Phenomena, Elsevier (2004) 3. G. Gottstein, Physikalische Grundlagen der Materialkunde (in German), Springer (2007)
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Focused Ion Beam Microscopy: Basics and Applications					
Module no. 11-01-9063	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. rer. nat. Leopoldo Molina-Luna		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-9063-vl	Focused Ion Beam Microscopy: Basics and Applications	0	Lecture	2

2	**Study Content** The focused ion beam (FIB) microscope has gained widespread use in the materials sciences over the last several years and has become an indispensable tool for materials characterization and micromachining. This lecture will cover the basics and applications of focused ion beam microscopy relevant for the materials sciences: (a) ion sources, (b) ion optics, (c) ion-solid interaction, (d) ion milling, sputtering and deposition, (e) scanning ion microscopy, (f) simulation of the transport of ions in matter, and (g) applications including focused ion beam lithography and micromachining.
3	**Learning Outcomes**
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, optional, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, optional, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature**
10	**Comment**

Module Description

Module name					
Fundamentals and Techniques of Modern Surface Science					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
11-01-8202	4 CP	120 h	90 h	1 Semester	Every 2. semester
Language of Instruction			**Person responsible for the Module**		

English	Prof. Dr. Wolfram Jaegermann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8202-vl	Fundamentals and Techniques of Modern Surface Science	0	Lecture	2

2 Study Content

- Vacuum techniques
- Auger-electron spectroscopy (AES)
- X-ray photoelectron spectroscopy (XPS)
- Ultraviolett photoelectron spectroscopy (UPS)
- Inverse photoemission spectroscopy (IPE, BIS)
- Electron energy loss spectroscopy (ELS,HREELS)
- X-ray absorption spectroscopy (XAS, NEXAFS)
- Thermal desorption spectroscopy (TDS)
- High energy electron diffraction (LEED)
- Ion scattering (ISS, LEISS)}
- Scanning tunneling microscopy (STM)
- Atomic force microscopy (AFM)

3 Learning Outcomes

The student has been introduced to the main methods used in modern surface science, he/she is familiar with the basic physical processes used for the different techniques, he/she has learned for which problems and how the techniques are applied in surface science, she/he has been introduced to the main materials science questions related to the use and application of these techniques, the student has the competence to judge when the application of these techniques is of use in his/her future scientific life, he/she is qualified to evaluate experimental and theoretical results obtained with these techniques, the student has obtained a first insight in modern surface science research and techniques applied for continuing experimental work in this field, he/she has obtained basic competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

recommended: modules “Quantum Mechanics for Materials Science”, basic knowledge of surface and interface science

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7 Grading

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. W.Mönch: Semiconductor Surfaces and Interfaces (Springer, 2001) 2. G.Ertl, J.Küppers: Low Energy Electrons and Surface Chemistry (VCH, 1974) 3. M.A.van Hove, S.Y.Tong: Surface Crystallography by LEED (Springer, 1979) 4. D.P.Woodruff, T.A.Delchar: Modern Techniques in Surface Science (Cambridge University Press, 1986) 5. D.Briggs, M.P.Seah: Practical Surface Analysis (Wiley, 1996) 6. St.Hüfner: Photoelectron Spectroscopy (Springer, 1994) 7. M.Cardona, L.Ley: Photoemission in Solids I + II (Springer) 8. M.Grasserbauer, H.J.Dudek, M.F.Ebel: Angewandte Oberflächenanalyse (Springer, 1986) 9. C.D.Wagner, W.M.Riggs, L.E.Davis, J.F.Moulder, G.E.Muilenberg: Handbook of X-ray Photoelectron Spectroscopy (Perkin-Elmer 1979) 10. C.S.Fadley: The Study of Surface Structures by Photoelectron Diffraction and Auger Electron Diffraction (Synchrotron Radiation Research: Advancesin Surface and Interface Science, Vol 1: Techniques, Plenum Press, 1992) 11. H.-J.Güntherodt, R.Wiesendanger: Scanning Tunneling Microscopy I-III (Springer, 1994) 12. J.T.Yates: Experimental Innovations in Surface Science (Springer, 1997)
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Fundamentals and Technology of Solar Cells					
Module no. 11-01-2005	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Wolfram Jaegermann		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	11-01-8401-vl	Fundamentals and Technology of Solar Cells	0	Lecture	2
2	**Study Content** • energy resources and scenarios • fundamentals of semiconductor and device physics • preparation and properties of single crystalline Si cells, compound semiconductor cells, high performance cells, thin film solar cells				
3	**Learning Outcomes** The student has gained the information to address and judge energy topics in their relevance for future technology areas, he/she has gained a broad understanding of semiconductor physics as background of the working principles of solar cells, he/she has been introduced to the materials science challenges given for the different cell technologies, he/she has learned which preparation and processing techniques are involved in the manufacturing and improvement of solar cells, he/she is qualified to evaluate experimental and theoretical methods for possible future research in solar cell basic science and technology, he/she has obtained the competence to follow advanced textbooks and scientific literature.				
4	**Requirements for Participation** recommended: modules “Surfaces and Interfaces”, “Quantum Mechanics for Materials Science”, “Electrochemistry in Energy Applications I: Converter Devices”				
5	**Form of Examination** Course Examination: • [11-01-8401-vl] (Technical Examination, Technical Examination, Standard)				
6	**Requirements on the Award of Credit Points** passing of exam				
7	**Grading** Course Examination: • [11-01-8401-vl] (Technical Examination, Technical Examination, Weight: 1, Standard)				
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science				
9	**Literature** 1. W. Jaegermann, Solar Cells, Lecture material (latest version 2010) 2. Basic Semiconductor Physics Books e.g. Sze, Semiconductor Physics 3. Different specialized books and reviews on solar cells, to be announced				
10	**Comment** Cycle: each summer semester				

Module Description

Module name					
Graphen and Carbon Nanotubes - from fundamentals to applications					
Module no. 11-01-2008	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Ralph Michael Krupke		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2008-vl	Graphen and Carbon Nanotubes - from fundamentals to applications	0	Lecture	2

2 Study Content

- Synthesis of graphene and carbon nanotubes
- Structure – property correlation
- Electrical and optical properties
- Device fabrication
- Potential applications

3 Learning Outcomes

The student has gained a basic knowledge in the fundamentals of graphene and carbon nanotubes. He/she is able to understand how the atomic structure of a carbon allotrope determines its properties. He/she is able to understand the electrical and optical properties of nanocarbons and its implications for future applications. He/she is qualified in characterisation techniques and device fabrication techniques. The student has the competence to follow scientific literature and the knowledge that is required to conduct research in the field.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. S. Reich, C. Thomsen, J. Mautzsch, Carbon Nanotubes: Basic Concepts and Physical Properties, WILEY-VCH, 2004. 2. A. Jorio, G. Dresselhaus, M. Dresselhaus (Eds.), Carbon Nanotubes: Advanced Topics in the Synthesis, Structure, Properties and Applications, Series: Topics in Applied Physics Vol 111, Springer, 2008. 3. S. Heinze, J. Tersoff, P. Avouris, Carbon nanotube electronics and optoelectronics, Materials Today Vol 9, Page 46-54, 2006. 4. P. Avouris, M. Freitag, V. Perebeinos, Carbon-nanotube photonics and optoelectronics, Nature Photonics Vol 2, Page 341-350, 2008. 5. F. Bonaccorso, A. Lombardo, T. Hasan, Z. Sun, L. Colombo, A. Ferrari, Production and processing of graphene and 2d crystals, MaterialsToday Vol15, Page 564-589, 2012. 6. F. Bonaccorso, Z. Sun, T. Hasan, A. Ferrari, Graphene Photonics and Optoelectronics, Nature Photonics Vol 4, Page 611-622, 2010.
10	**Comment** Cycle: each summer semester

Module Description

Module name High Pressure Materials Synthesis					
Module no. 11-01-7602	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Ralf Riedel		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7602-vl	High Pressure Materials Synthesis	0	Lecture	2

2 Study Content

- Pressure as a thermodynamic parameter; thermodynamics of deformation; equation of

	state • Phase transitions and chemical reactions • High-pressure apparatuses • Chemistry at high pressures: synthesis of new materials
3	**Learning Outcomes** The student has gained a basic knowledge on high-pressure physics and materials synthesis techniques. He/she is able to identify the advantages and disadvantages of each HP preparative method for different applications and needs. He/she is qualified to evaluate high-pressure techniques for the synthesis of structural and functional materials with new dense structures. The student has a first insight in modern high-pressure research and a beginner's competence to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. N.W. Ashcroft, N.D. Mermin, Festkörperphysik, Oldenbourg, München, 2007. 2. C. Kittel, Introduction to solid state physics, J. Wiley & Sons, New York, 1986. 3. L.D. Landau, E.M. Lifshitz, Course of Theoretical Physics, vol. 7: Theory of Elasticity, Pergamon Press, London, 1975. 4. P.W. Atkins, Physical Chemistry, Oxford University Press, Oxford, 1998. 5. W.B. Holzapfel, N. S. Isaacs, High-pressure Techniques in Chemistry and Physics, Oxford University Press, Oxford, 1997. 6. M.I. Eremets, High Pressure Experimental Methods, Oxford University Press, Oxford, 1996.
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Hysteresis in Magnetic Materials					
Module no. 11-01-2024	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr.-Ing. Oliver Gutfleisch		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2024-vl	Hysteresis in Magnetic Materials	0	Lecture	2

2 Study Content

This lecture covers first some fundamental theory of magnetic materials, then design principles, and (micro)structure-property-relations in connection with the resulting thermal and magnetic hystereses. It covers the ground from intrinsic to extrinsic magnetic properties and develops strategies for the processing and fabrication of various functional magnets leading to variety of applications in energy technologies, sensors and actuators in robotics and biomedicine.

The main topics that will be studied in framework of this course are:
· Magnetism and hysteresis
· Physics of magnetic materials: from isolated moments to ordered arrangements
· Thermodynamics of magnetic solids
· Magnetic domains
· Micromagnetic theory
· Coercivity mechanisms
· Hard magnetic materials: maximizing hysteresis
· Hysteresis in fine particles and nanostructured materials: below the critical single-domain size
· Soft magnetic materials: minimizing hysteresis
· Magnetoelastic materials: magneto-structural coupling
· Magnetocaloric materials: balancing near the critical point
· Magnetic materials for efficient energy conversion, sensors and actuators
· Hysteresis in magnetic multiferroics and heterostructures: combining magnetism with additional functionalities
· Magnetic materials for recording and computers
· Magnetic Materials in Medicine and Biology

3 Learning Outcomes

Students will be able apply their acquired knowledge on magnetic hysteresis to the understanding of advanced functional principles of magnetic materials, which are key components of modern technologies with broad spectra of applications. The students will

	understand the basic principles of high coercivity in advanced permanent magnet (Nd-Fe-B, Sm-Zr-Co-Cu-Fe, Ferrites etc.). The students will understand the basics of materials with magneto-structural first-order phase transitions (La(FeSi)13-based, FeRh, Heusler alloys etc) and they will understand the critical role of thermal and magnetic hysteresis in solid state magnetic refrigeration. Further, the important role of magnetic hysteresis optimization in soft magnetic materials and fine magnetic particles for medicine and biology will be elucidated. The knowledge and skills gained in this course will help the students to work with advanced textbooks and scientific literature on functional magnetic materials and will qualify them to assess magnetic materials as key energy and technology enablers for wind energy and electromobility.
4	**Requirements for Participation** recommended: modules "Functional Materials" and "Magnetism and Magnetic Materials"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. J. M. D. Coey, "Magnetism and Magnetic Materials", Cambridge University Press, 2010 2. B.D. Cullity and C.D. Graham, "Introduction to Magnetic Materials", John Wiley &Sons, 2009 3. R. O’Handley, "Modern Magnetic Materials", John Wiley &Sons, 2000, 4. R. Hilzinger and W. Rodewald, "Magnetic Materials", VAC, 2013 5. A. Hubert and R. Schäfer, "Magnetic Domains", Springer, 2000 6. S. Chikazumi, "Physics of Ferromagnetism", Oxford Science Publ., 1997 7. S. Blundell, "Magnetism in condensed matter", Oxford master Series in Cond Matt Phys., 2012 8. D. Jiles, "Magnetism and magnetic materials", Chapman & Hall, 1991
10	**Comment** Cycle: each summer semester

Module Description

Module name					
In-situ Transmission Electron Microscopy					
Module no. 11-01-2017	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Christian Klaus Ulrich Kübel		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2017-vl	In-situ Transmission Electron Microscopy	0	Lecture	2

2 Study Content

In-situ electron microscopy techniques are becoming increasingly established to understand fundamental processes during synthesis, processing and application of functional materials at the atomic and nanometer scale. Different stimuli ranging from heating or electrical biasing to mechanical deformation and various liquid and gas environments are used to model selected processes and follow the structural changes with the full range of advanced imaging techniques in the TEM to correlate structure and properties of materials and identify transient states in reactions.
This lecture will (a) review the most important imaging techniques in the TEM (BF-/DF-/HRTEM, STEM), analytical techniques (EELS, EDX) and recent developments such as ACOM orientation mapping and other 4D-STEM techniques, (b) discuss electron beam effects in materials, (c) introduce various in-situ thermal, electrical, mechanical, liquid and gas phase setups, and (d) their application to understand processes in (nanostructured) materials. The aim is to provide the student with tools for advanced atomic and nanoscale characterization of materials and processes.

3 Learning Outcomes

The students will be introduced to the possibilities modern electron microscopy imaging and spectroscopy techniques offer for advanced atomic/nanoscale structural and chemical characterization and the different in-situ approaches that can be implemented to follow complex processes in materials. The aim is to develop an idea how materials research can benefit from (in-situ) electron microscopy and to provide the students with a basis to interpret (in-situ) electron microscopy data and to recognize challenges and pitfalls, enabling independent critical analysis of his/her own experimental research and published structural characterization.

4 Requirements for Participation

recommended: module “Transmission Electron Microscopy (TEM)”

	recommended: module “Scanning Transmission Electron Microscopy for Materials Science”
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Transmission Electron Microscopy, D.B. Williams and C.B. Carter, (2nd Ed.) Springer Verlag 2. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, R. Egerton, Springer Verlag 3. Stephen J. Pennycook, Peter D. Nellist (Eds.): Scanning Transmission Electron Microscopy - Imaging and Analysis 4. G. Dehm, J.M. Howe, J. Zweck (Eds.): In-situ Electron Microscopy, Wiley-VCH 5. T.W. Hansen, J.B. Wagner (Eds.): Controlled Atmosphere Transmission Electron Microscopy, Springer 6. A. Ziegler, H. Graafsma, X.F. Zhang, J.W.M. Frenken (Eds.): In-situ Materials Characterization – Across Spatial and Temporal Scales, Springer
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Interfaces: Wetting and Friction					
Module no. 11-01-2016	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Robert Stark		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	11-01-2016-vl	Interfaces: Wetting and Friction	0	Lecture	2

2	**Study Content** Phenomena at the fluid-solid boundary play an important role in many technical applications such as lubrication, microfluidics, biotechnology or printing. The lecture focuses on the fundamental aspects. Topics include: Liquid surfaces, thermodynamics of interfaces, the electric double layer, surface forces, contact angle, wetting, surface modification, microfluidics, friction, lubrication and wear, cleaning.
3	**Learning Outcomes** The students are able to explain phenomena at the liquid solid interface in terms of physical and chemical properties. They know how to select materials and how to modify their surfaces in order to achieve the desired wetting behavior in a technical environment.
4	**Requirements for Participation** recommended: basic physical chemistry and physics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Butt, Graf, Kappl, Physics and Chemistry of Interfaces, Weinheim 2003. 2. Israelachvili, Intermolecular & Surface Forces, San Diego 1991. 3. Persson, Sliding Friction – Physical Principles and Applications, Berlin 2000.
10	**Comment** Cycle: each summer semester

Module Description

Module name

Magnetism and Magnetic Materials

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-2001	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Lambert Alff

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2001-vl	Magnetism and Magnetic Materials	0	Lecture	2

2 Study Content

- Basic notions of magnetism
- Magnetism in atoms and ions
- Magnetism in metallic materials
- Crystal field symmetry and Exchange Interaction
- Magnetically ordered structures
- Magnetic order, symmetry and phase transitions
- Micromagnetism and domain behavior
- Experimental methods in magnetism
- Selected (hot) topics from current research

3 Learning Outcomes

The student is able to remember the basic notions of magnetism for a broad range of situations and materials. The student has the competence to differentiate different types of magnetism and their origin, and to correlate them with materials properties. He/she is qualified to evaluate experimental and theoretical methods for goal-oriented research in the area of magnetism and magnetic materials. The student remembers modern magnetic materials and their use in current applications. The student has a first insight in modern research in magnetism and magnetic materials and a beginner's competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

recommended: module „Quantum Mechanics for Materials Science"

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. S. Blundell: Magnetism in Condensed Matter, Oxford University Press (2001) 2. J. M.D. Coey: Magnetism and Magnetic Materials, Cambridge University Press (2009) 3. D. Jiles: Introduction to Magnetism and Magnetic Materials, Chapman & Hall (2001) 4. R. Skomski: Simple Models of Magnetism, Oxford University Press (2008) 5. N. Spaldin, Magnetic Materials, Cambridge University Press (2006) 6. L. Alff, Magnetismus und magnetische Materialien, Lecture notes (2004)
10	**Comment** Cycle: each winter semester

Module Description

Module name Materials Chemistry					
Module no. 11-01-7292	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Ralf Riedel		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7292-vl	Materials Chemistry	0	Lecture	2

2 Study Content

- Introduction
- Silicon: Methods for the Preparation of High Purity Silicon
- Reaction in the Gas Phase: Mond-Process, van-Arkel-de-Boer Process, CVD (Thermodynamics of CVD Examples), Spray Pyrolysis
- Solvothermal Syntheses
- Silicones and Silazanes: Synthesis from Organo Chloro Silanes,

	• Silicon-Containing Polymers: Polysiloxanes, Polysilazanes, Polysilylcarbodiimides, Polysilanes, Polycarbosilanes • Boron-Containing Polymers • Polymer-Derived Ceramics and Their Applications (Fibers, Ceramic Brake Disc) • High Pressure Syntheses, Diamond Anvil Cell • Sol-Gel Processing I (Alkoxides, Transalkoholyse, Base- und Acid-Induced Catalysis of Si(OR)4/H2O) • Sol-Gel Processing II (Polycondensation, Cross-Condensation), • Organic Light Emitting Diodes • Biomineralisation
3	**Learning Outcomes** The student has gained an overview on and remembers different synthesis techniques for inorganic materials. Furthermore, he/she has gained the competence to evaluate the relationship between the synthesis method and the properties of the inorganic materials materials. The student has the competence to evaluate experimental and theoretical methods for goal-oriented research in the area of inorganic materials. The student has a first insight in modern preparative techniques for inorganic materials and a beginner's competence to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. U. Schubert, N. Hüsing: „Synthesis of Inorganic Materials“, Wiley-VCH, Weinheim, 2000 2. David Segal: „Chemical Synthesis of Advanced Ceramic Materials“, Cambridge University Press, 1991 3. Bill, Wakai, Aldinger, „Precursor-Derived Ceramics“, Wiley-VCH, 1996
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Materials chemistry in electrocatalysis for energy applications					
Module no. 11-01-2022	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrike Kramm		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2022-ue	Exercises Materials chemistry in electrocatalysis for energy applications	0	Exercise	1
11-01-2022-vl	Materials chemistry in electrocatalysis for energy applications	0	Lecture	2

2 Study Content

Within the synthesis process of electrocatalysts it is important to consider the distinct application target already at an early stage. In this lecture, we will discuss the most important fabrication processes for electrocatalysts, important techniques for their characterization and electrochemical evaluation. The selected examples focus on energy applications such as fuel cells and water electrolysis.

Topics:
Electrocatalysis (Introduction, Fundamentals, Reaction mechanisms)
Catalyst synthesis (Preparation of nanoparticles, Thin films, New and innovative catalyst concepts)
Characterization (Selected spectroscopic and analytical methods, In-situ and post-mortem characterization)
Important Parameters for catalyst application (Activity, Selectivity, Stability)
Applications (Different types of fuel cells, water splitting reactions, and others)

3 Learning Outcomes

Due to the parallel exercises in which important recent publications on catalyst synthesis, characterization and applications are evaluated, the students become experts in the field of materials development for electrocatalysis. They will be able to perform a qualified evaluation of related publications, proposals etc.. In addition to this, they learn how to present research results. For their own work, the students are able to decide on their own, which characterization techniques are most suited for the one or other types of catalyst as

	also the main aspects for each of the characterization methods will be discussed.
4	**Requirements for Participation** A Bachelor degree in natural science or engineering. It is recommended to study the basics of electrochemistry (moduls 11-01-7300 or 07-04-0006) in parallel or before.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** To be announced in the lecture
10	**Comment** Cycle: each summer semester

Module Description

Module name

Materials Research with Energetic Ion Beams - Basic Aspects and Nanotechnology

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-7042	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. phil. nat. Christina Trautmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-7042-vl	Materials research with	0	Lecture	2

		energetic ion beams - basic aspects and nanotechnology			

2	**Study Content** • ionizing radiation • particle-solid interaction • energy loss • radiation damage • damage analysis • nanotechnology with ion beams • accelerator technology
3	**Learning Outcomes** The course provides an overview of the unique possibilities using high-energy heavy ions for the modification of material properties and production of micro and nanostructures. The student becomes familiar with basic interaction processes of particle beams and solids. Knowledge is gained how ion radiation deteriorates materials and how this radiation damage is analysed by different methods. The lecture also gives insight into ion beam technology at large scale accelerator facilities and how to perform irradiation experiments by adjusting and controlling specific beam parameters. The student gets a glimpse on the present activities in the field of ion track technology using individual ion projectiles as structuring tool and will be familiar with ion-beam produced micro- and nanostructures and a broad spectrum of applications.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** will be provided during the lecture
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Materials Science of Thin Films					
Module no. 11-01-2004	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Lambert Alff		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2004-vl	Thin Film Fabrication and Surface Techniques	0	Lecture	2

2 Study Content

- Introduction to thin film technology
- Nucleation: Thermodynamics and kinetics
- Structure and strain
- Thermal Evaporation
- Sputtering
- Chemical vapor deposition (CVD)
- Molecular beam epitaxy (MBE)
- Pulsed laser deposition (PLD)
- Thin film deposition of oxides
- Thin films for solar cells

3 Learning Outcomes

The student has gained a broad overview on and remembers relevant thin film deposition methods. He/she is able to identify the advantages and disadvantages of each deposition method for different applications and needs. The student has the competence to apply fundamental thin film science to novel materials. The student has the competence to differentiate different types of deposition methods according to their physical and chemical principles. He/she is qualified to evaluate thin film methods for goal-oriented research in the diverse fields of thin film applications. The student has a first insight in modern research in thin films and a beginner's competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

none

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. M. Ohring: Materials Science of Thin Films, Academic Press (2002) 2. L. B. Freund and S. Suresh: Thin Film Materialss, Cambridge University Press (2003). 3. R. Eason (Ed.): Pulsed Laser Deposition of Thin Films, Wiley (2007) 4. 17. IFF-Ferienkurs: Dünne Schichten und Schichtsysteme, Forschungszentrum Jülich (1986)
10	**Comment** Cycle: each summer semester

Module Description

Module name

Mathematical Methods in Materials Science

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-3018	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Apl. Prof. Dr. rer. nat. Yuri Genenko

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8662-vl	Mathematical Methods in Materials Science	0	Lecture	2

2 Study Content

- Linear ordinary differential equations: constant and variable coefficients

	• Relaxation processes and oscillations in electrical circuits, parametric resonance • Normal vibrational modes of polyatomic molecules: Lagrangian mechanics • Linear partial differential equations: elliptic, hyperbolic, and parabolic equations • Method of Fourier and Laplace transforms • Diffusion in composite media: interface resistance • Diffusion of foreign atoms to cylindrical and spherical precipitates • Diffusion of magnetic field in a metal • Solidification processes in an undercooled melt: Stefan problem • Injection of electrons into dielectrics and organic semiconductors • Green’s function technique • Bifurcations and phase transitions in open biological and chemical systems • Self-organization in nonlinear active media
3	**Learning Outcomes** The student is able to use advanced mathematical techniques for exactly, or approximately, solving linear ordinary and partial differential equations. He/she is able to implement these techniques for dealing with a variety of typical problems in materials science. He/she is able to follow sophisticated texts on these techniques and to address complex issues of that sort him- or herself.
4	**Requirements for Participation** recommended: basic knowledge in mathematics, physics, and materials science
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. G.B. Arfken, H.J. Weber: Mathematical Methods for Physicists, Academic Press, New York (1995) 2. H.S. Carslaw, J.C. Jaeger: Conduction of Heat in Solids, Clarendon Press, Oxford (1993) 3. J. Crank: The Mathematics of Diffusion, Clarendon Press, Oxford (1994) 4. H. Heuser: Gewöhnliche Differentialgleichungen – Einführung in Lehre und Gebrauch, Teubner, Stuttgart (1995) 5. G. Lehner: Elektromagnetische Feldtheorie für Ingenieure und Physiker, Springer, Berlin (1996) 6. W. Richter: Einführung in Theorie und Praxis der partiellen Differentialgleichungen,

	Spektrum, Heidelberg (1995)
10	**Comment** Cycle: each winter semester

Module Description

Module name Mechanical Properties of Ceramic Materials					
Module no. 11-01-9332	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr.-Ing. Jürgen Rödel		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9332-vl	Mechanical Properties of Ceramic Materials	0	Lecture	2

2 Study Content

- Overview of technical ceramics in relation to their mechanical properties
- Stress intensity factor, mechanical energy release rate, instability criterion
- Fracture strength, fractography
- Crack tip toughness, crack shielding, theory of R-curves
- Process zone mechanisms: phase transformation, microcracking, ferroelasticity
- Fiber reinforcement, micromechanics of whiskers and particle toughening
- Mechanics of laminates
- Subcritical crack growth and fatigue, life time predictions
- Creep, sintering
- Thermal shock, hardness and wear
- Measurement methodology, Weibull's law

3 Learning Outcomes

The student has obtained a global and detailed view of the different mechanical properties of ceramic materials, composites and structures. This knowledge allows him/her to choose materials with adequate properties for a given application. The student understands the phenomenon responsible for crack extension and brittle fracture under the combined effects of applied loading, temperature, time, chemical environment. He/she can choose appropriate measurement techniques to get reliable data. The student understands the influence of microstructure on the mechanical properties of ceramic materials. He/she has the competence to devise mechanisms of optimizing existing ceramic materials and to develop new materials with improved properties. The student has a first insight into

	modern research in the field of mechanics of ceramics and is competent to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. B. Lawn: Fracture of Brittle Solids – 2nd Edition, Cambridge University Press (1993) 2. D. Munz, T. Fett: Ceramics - Mechanical properties, failure behaviour, materials selection, Springer Verlag Berlin Heidelberg (1999) 3. D.J. Green: An introduction to mechanical properties of ceramics, Cambridge University Press (1998)
10	**Comment** Cycle: each winter semester

Module Description

Module name Mechanical Properties of Metals					
Module no. 11-01-2006	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Apl. Prof. Dr.-Ing. Clemens Müller		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact**

				Teaching	Hours per Week
	11-01-9092-vl	Mechanical Properties of Metals	0	Lecture	2

2	**Study Content** • Microstructure – Property Relationship • Tensile Testing • Fracture Toughness • Fatigue Life Time • Fatigue Crack Propagation • Crack Closure Effects • Long Crack and Short Crack Behaviour
3	**Learning Outcomes** The student is able to remember the basic notions of the behaviour of metallic materials under static and dynamic loading. He/she has the competence to differentiate the relevant mechanisms and their microstructural dependence. They are able to decide about the optimal microstructure for the prevailing mechanical loading and have basic knowledge about methods to produce the relevant microstructures. He/she is qualified to assess experimental and theoretical methods for goal-oriented research in the area of improving mechanical properties by microstructural optimization. The student has a beginner's competence to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** recommended: Bachelor module "Materials Science IV: Mechanical Properties"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Mechanical Behavior of Engineering Materials, J. Rösler, Springer Verlag 2. Materials Science and Engineering, R. W. Cahn et al. VCH-Verlag 3. Materials for Engineering, J. W. Martin. The Institute of Materials, London 4. Deformation and Fracture Mechanics of Engineering Materials, R.W. Hertzberg, John Wiley & Sons, Inc

	5. Werkstoffkunde und Werkstoffprüfung, W. Domke. Verlag W. Girardet, Essen
10	**Comment** Cycle: each winter semester

Module Description

Module name

Micromechanics and Nanostructured Materials

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
11-01-7070	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr.-Ing. Karsten Durst

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
11-01-7070-vl	Micromechanics and Nanostructured Materials	0	Lecture	2

2 Study Content

The lecture treats new micromechanical testing methods and size effects in the mechanical properties of metals and nanostructured/nanosized materials. The first part of the lectures is concerned with small scale testing methods starting with nanoindentation testing and contact mechanics for evaluation of the local mechanical properties. This is followed by an overview of new in-situ testing methods, where mechanical testing on small scale samples is conducted inside the electron microcope and deformation mechanism can be analyzed during mechanical testing. Finally, techniques for thin film testing, like Bulge test or tensile testing of coated substrates is presented and the failure and damage mechanism are discussed. The second part of lecture series focuses on size effects in the mechanical properties, starting with small scale samples like pillars and thin films as well as size effects occurring during indentation testing. At the end, deformation mechanisms and size effects found in bulk nanostructured materials are discussed, focusing on strain rate sensitivity and deformation mechanism occurring at grain boundaries. The lecture is intended for master students having a background in deformation mechanism and mechanical properties of metallic materials.

3 Learning Outcomes

The student develops a basic understanding of the different testing methods and deformation mechanism for small scale mechanical properties. The student can discuss in detail the governing equations for Nanoindentation, bulge testing as well as standard uniaxial testing approaches. Based on the knowledge of the deformation behavior at the macroscopic length scale, the student can describe the deformation resistance of materials

	at small length scales and for small scale microstructures using concepts like theoretical strength or Hall Petch break down. Finally the students gain a first insight into small scale mechanical testing methods as well as the deformation mechanism in nanocrystalline materials to follow advanced textbooks and scientific literature.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 15 min, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. A.C. Fischer Cripps: Nanoindentation, Springer 2. J. Rösler: Mechanisches Verhalten der Werkstoffe, Springer 3. A.C. Fischer Cripps: Introduction to contact mechanics, Springer 4. D. Tabor: The Hardness of metals, Oxford University Press 5. K.L. Johnson: Contact mechanics, Cambridge University Press 6. DIN EN ISO 14577: Instrumentierte Eindringprüfung 7. W. C. Oliver, G. M. Pharr., Beschreibung der Oliver-Pharr Methode, J Mater Res, 7(6):1564–1580, 1992 8. E. Arzt: Review der Größeneffekte, Acta Mater, 46(16):5611–5626, 1998
10	**Comment** Cycle: each summer semester

Module Description

Module name Modern Steels for Automotive Applications					
Module no. 11-01-	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester

9090					

Language of Instruction	**Person responsible for the Module**
English	Apl. Prof. Dr.-Ing. Clemens Müller

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9090-vl	Modern steels for automotive applications	0	Lecture	2

2 Study Content

- Production of steels
- Thermomechanical treatments (TMT), microstructures, deformation and strengthening modes
- Requirements for automotive applications
- Modern high strength steels, TMT, microstructures, deformation and strengthening modes
- High formability steels, TMT, microstructures, deformation and strengthening modes

3 Learning Outcomes

The student has gained an advanced knowledge of the processing (TMT) of modern steels, their microstructures, their deformation and strengthening modes as well as their mechanical properties. He/she is able to correlate the mechanical properties with microstructural features and has an advanced knowledge of the methods to produce the required microstructure. The student has a first insight in the special requirements on steels/materials for automotive applications and a beginner's competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)

8 Usability of the Module

	M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. F.B. Pickering „Physical Metallurgy and the design of steels“ Appl. Sci. Publ. 1978 2. D. Peckner and I.M. Bernstein “Handbook of stainless steels” McGraw-Hill 1977 3. F. Rapatz “Die Edelstähle” Springer 1962 (in German)
10	**Comment** Cycle: each summer semester

Module Description

Module name

Organic Functional Materials: From LCD to Molecular Circuits

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-2026	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. Peer Kirsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2026-vl	Organic Functional Materials: From LCD to Molecular Circuits	0	Lecture	2

2	**Study Content** Introduction into chemistry, physics, applications and industrial aspects of organic functional materials for electronics industry. The focus of the course is on small molecules and their supramolecular chemistry: •Materials for liquid crystal displays (LCD): design, synthesis and structure-property relationships •Basics of organic electronics: physics and structures of organic conductors, semiconductors and superconductors •Materials for organic light emitting diode (OLED) displays and their function •Organic semiconductors for printed field effect transistors (OFET) •Organic photovoltaics (OPV) and dye-sensitized solar cells (DSC) •Basics of molecular nanoelectronics: physics, structures and methods •Unimolecular wires, diodes, transistors, memory and circuits
3	**Learning Outcomes** •Understanding of design and structure-property relationships of functional materials based on organic small molecules. •Understanding of the physics and function of organic electronic devices: OLED, OFET,

	OPV •Understanding of physics, materials, design and functional limitations of devices based on single molecules and self-assembled monolayers
4	**Requirements for Participation** Bachelor degree in natural science or engineering. It is highly recommended to obtain a good background of basic solid state physics and organic chemistry.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) written or oral exam
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. D. Dunmur, T. Sluckin, Soap, Science, & Flat-Screen TVs: A History of Liquid Crystals, Oxford University Press, 2010. 2. J. A. Castellano, Liquid Gold: The Story of Liquid Crystal Displays and the Creation of an Industry, World Scientific, 2005. 3. S. Hunklinger, Festkörperphysik, De Gruyter, 2018 4. P. Kirsch, M. Bremer, Angew. Chem. Int. Ed. 2000, 39, 4216-4235. 5. P. Kirsch, M. Bremer, M. Klasen-Memmer, K. Tarumi, Angew. Chem. Int. Ed. 2013, 52, 8880-8896. 6. H. E. Katz, Z. Bao, S. L. Gilat, Acc. Chem. Res. 2001, 34, 359-369. 7. J.-L. Brédas, D. Beljonne, V. Coropceanu, J. Cornil, Chem. Rev. 2004, 104, 4971-5003. 8. V. Coropceanu, J. Cornil, D. A. Da Silva Filho, Y. Olivier, R. Silbey, J.-L. Brédas, Chem. Rev. 2007, 107, 926-952. 9. D. Hertel, C. D. Müller, K. Meerholz, Chem. Unserer Zeit 2005, 39, 336-347. 10. D. Wöhrle, O. R. Wild, Chem. Unser Zeit 2010, 44, 174-189. 11. D. Xiang, X. Wang, C. Jia, T. Lee, X. Guo, Chem. Rev. 2016, 116, 4318-4440. 12. M. Elbing, J. U. Würfel, M. Di Leo, H. B. Weber, M. Mayor, Nachrichten – Forschungszentrum Karlsruhe 2005, 37, 24-29.
10	**Comment** Cycle: each winter semester

Module Description

Module name Phase Transitions in Materials					
Module no. 11-01-9812	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Wolfgang Donner		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9812-vl	Phase Transitions in Materials	0	Lecture	2

2 Study Content

- Basic Thermodynamics
- Nucleation and Diffusion
- Energy nad Entropy
- Melting
- Precipitation
- Diffusionsless Transformations
- Ordering Transformations
- Magnetic Transitions
- Critical Phenomena

3 Learning Outcomes

Phase transitions are ubiquitous in Materials Science; close to such a transition, the response functions (i.e. physical properties) are enhanced. After taking this course, the student will be able to:

1. Classify phase transitions,
2. Relate the changes inside the materials to changes in their physical properties,
3. Choose appropriate characterization methods for phase transitions,
4. Critically review the literature about phase transitions,
5. Use the knowledge about phase transitions for his/her own scientific project.

4 Requirements for Participation

recommended: BSc in Materials Science, Physics or Chemistry; Course in Thermodynamics; Course in Scattering Methods

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination,

	Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Brent Fultz: Phase Transitions in Materials. Cambridge University Press 2014 2. Minoru Fujimoto: The Physics of Structural Phase Transitions. Springer 2005 also at: https://link.springer.com/book/10.1007%2Fb138153 3. P. Papon, L. Leblond, P.H.E. Meijer: The Physics of Phase Transitions. Springer 2006 also at: https://link.springer.com/book/10.1007%2F3-540-33390-8
10	**Comment** Cycle: each summer semester

Module Description

Module name Polymer Materials					
Module no. 11-01-3031	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr.-Ing. Jürgen Wieser		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-3031-vl	Polymer Materials	0	Lecture	3
2	**Study Content** Molecular structures and morphologies in polymers; Basics of polymer synthesis; mechanisms of additives, fillers and fibres in polymer compounds; viscoelasticity; creep and relaxation; rheology of polymer melts, glass transition and crystallisation of polymers; mechanical, thermal, optical and electrical properties of polymer compounds;				

	longterm behavior of polymers; characterization methods and procedures for polymers.
3	**Learning Outcomes** The student has gained an overview on typical morphologies in polymers and is able to discuss structure-property relationships and also the influence of kinetic parameters on the morphology. He/she can explain the role and the mechanisms of the most important classes of additives, fillers and fibres in polymer compounds. He/she can identify the appropriate characterization methods, testing devices and testing procedures for typical applications.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. G. Menges, Menges Werkstoffkunde der Kunststoffe, Hanser, München, 2011. 2. M. Schiller, Plastic Additives Handbook, Hanser, München, 2009. 3. T. Osswald, G. Menges, Material Science of Polymers for Engineers, Hanser, München, 2012.
10	**Comment** Cycle: each winter semester

Module Description

Module name Polymer Processing					
Module no.	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester

11-01-3030					

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr.-Ing. Jürgen Wieser

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-3030-vl	Polymer Processing	0	Lecture	2

2 Study Content

Processing of Polymers: Compounding, extrusion, injection moulding, thermoforming, blow moulding, welding, glueing and typical surface decorations and treatments

3 Learning Outcomes

The student has gained an overview on typical processing technologies for polymers. He/she is able to identify processing technologies for different applications. He/she can explain the plastification, the melt flow and the solidification characteristics of a thermoplastic resin and how the materials morphology develops during processing. He/she can identify typical failures which can result of inappropriate processing. The student is able to describe the most important machines and process steps.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)

8 Usability of the Module

M.Sc. Materials Science: Elective Courses Materials Science

9 Literature

1. W. Michaeli, Einführung in die Kunststoffverarbeitung, Hanser, München, 2010.
2. W. Knappe, Kunststoff-Verarbeitung und Werkzeugbau, Hanser, München, 1992.
3. F. Johannaber, W. Michaeli, Handbuch Spritzgießen, Hanser, München, 2004.

10	**Comment** Cycle: each summer semester

Module Description

Module name Porous Ceramics for Energy-Related Applications					
Module no. 11-01-2023	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. Magdalena Joanna Graczyk-Zajac		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2023-vl	Porous Ceramics for Energy-Related Applications	0	Lecture	2

2 Study Content

· General introduction to porous materials. Definition: porosity, pore size, surface area, pore volume. Ordered porosity, hierarchical porosity. Porosity determination: experiment and modeling
· Synthesis of porous ceramics: focus on the application-related porosity tailoring and functionalization.
· Properties of porous ceramics: focus on the thermal/hydrothermal/chemical stability of the porosity
· Applications of porous ceramics: past, state-of-the art and future technologies.
· Porous materials in batteries
· Porous materials in fuel cells and supercapacitors.
· Porous materials for gas storage
· Porous membranes for gas separation

3 Learning Outcomes

Immense research has been carried out on the synthesis and application of hierarchically organized porous solids over the last decade. This subject has become a hot topic and it will continue to prosper due to the variety of important, energy related applications such as charge and gas storage media and membrane supports.

This course aims at instructing students in a systematic, interdisciplinary and practice-oriented way about the application of porous ceramics in energy-related technologies It bridges the gap between the different "ways of thinking" in material science, chemistry and electrochemistry. It provides a firm grounding for advanced students who will gain a broad general overview on porous materials and a detailed knowledge on the processing and

	applications of this materials group.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Liu, P.S. and G.F. Chen, Porous Materials. 2014, Butterworth-Heinemann: Boston. Chapters 1,5,6,9,10 2. Espinal, L., Porosity and Its Measurement, in Characterization of Materials. 2012, John Wiley & Sons, Inc. 3. Su, B.-L., Hierarchically Structured Porous Materials for Energy Conversion and Storage, in Hierarchically Structured Porous Materials. 2011, Wiley-VCH Verlag GmbH & Co. KGaA. 4. Thommes, M., et al., Physisorption of gases, with special reference to the evaluation of surface area and pore size distribution (IUPAC Technical Report). Pure and Applied Chemistry, 2015. 87(9-10): p. 1051. 5. Wejrzanowski, T., et al., Appropriate models for simulating open-porous materials. 2017, 2017. 36(2): p. 6. 6. Schwieger, W., et al., Hierarchy concepts: classification and preparation strategies for zeolite containing materials with hierarchical porosity. Chemical Society Reviews, 2016. 45(12): p. 3353-3376. 7. Feinle, A., M.S. Elsaesser, and N. Husing, Sol-gel synthesis of monolithic materials with hierarchical porosity. Chemical Society Reviews, 2016. 45(12): p. 3377-3399.
10	**Comment** Cycle: each winter semester

Module Description

Module name
Properties of Ferroelectric Materials

Module no. 11-01-8411	Credit Points 4 CP	Workload 120 h	Self-study 90 h	Duration 1 Semester	Frequency Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. Jurij Koruza		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8411-vl	Properties of Ferroelectric Materials	0	Lecture	2

2 Study Content

- Polarization mechanisms in gases, liquids and solids
- Symmetry-property relations in polar materials: piezo-, pyro- & ferroelectricity
- Landau theory of phase transitions
- Domain structure of uni- and polyaxial ferroelectrics
- Coupling of ferroelectric & ferroelastic behavior
- Domain reversal & ferroelectric hysteresis
- Domain walls, small-signal behavior, Rayleigh law
- Damage mechanisms, aging & fatigue
- Technically relevant ferroelectrics
- Special cases: Antiferroelectrics, relaxors, multiferroics...
- Typical applications of ferroelectric materials

3 Learning Outcomes

The student can identify different mechanisms of electrical polarization and is able to deduce possible polarization effects from information about the structure of a material. He/she can chose basic characterization techniques and adapt them to the requirements of a given problem. The student understands the influence of domain structures on the properties of a ferroelectric/ferroelastic and knows how to manipulate these structures to obtain optimum material response for a specific application. He/she has the competence to devise methods of optimizing existing ferroelectric materials and to develop new materials with improved properties. The student has a first insight in modern research in ferroelectrics and is competent to follow advanced textbooks and scientific literature.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

	passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. S. Sonin and B. A. Strukow: Einführung in die Ferroelektrizität, Vieweg Verlag (1982) 2. R. E Newnham: Properties of materials – Anisotropy / Symmetry / Strcuture, Oxford University Press (2005). 3. B Jaffe, W. R. Cook, and H. Jaffe: Piezoelectric ceramics, Academic Press (1971) 4. M. E. Lines and A. M. Glass: Prinicples and applications of ferroelectrics and related materials, Oxford University Press (1977)
10	**Comment** Cycle: each summer semester

Module Description

Module name					
Quantum Materials: Theory, Numerics, and Applications					
Module no. 11-01-2019	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Hongbin Zhang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-2019-vl	Quantum Materials: Theory, Numerics, and Applications	0	Lecture	2
2	**Study Content** In this course, we will focus on several classes of Solid State Materials where Quantum Mechanics can be applied to get the physical properties, including but not limited to * Wannier functions and tight-binding model * metals, insulators, and metal-insulator transition * ferroelectric polarization, i.e., Berry phase theory				

	* graphene * topological insulators * magnetism, (super) exchange interaction * transport, e.g., diffusive, mesoscopic * linear-response theory * surface and interface * phonons * mean-field theory and strong correlations All the topics in this course will be discussed by solving simple models numerically, with Python modules prepared for/developed during the courses. Hands-on tutorials will be arranged with access to clusters where calculations can be done.
3	**Learning Outcomes** The students develop a fundamental understanding on the quantum origin of various physical properties, in close connection to their future researches. They obtain a deep understanding of the theory behind each class of phenomena.
4	**Requirements for Participation** recommended: basic quantum mechanics and basic knowledge of programming
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** A handout will be distributed for each lecture, with detailed theory, guide for numerical implementation, and further literature.
10	**Comment** Cycle: each summer semester

Module Description

<table>
<tr><td colspan="6">Module name
Scanning probe microscopy in materials science</td></tr>
<tr><td>Module no.
11-01-7060</td><td>Credit Points
4 CP</td><td>Workload
120 h</td><td>Self-study
90 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
English</td><td colspan="3">Person responsible for the Module
Prof. Dr. rer. nat. Robert Stark</td></tr>
</table>

<table>
<tr><td rowspan="3">1</td><td colspan="5">Courses of the Module</td></tr>
<tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td>11-01-7060-vl</td><td>Scanning probe microscopy in materials science</td><td>0</td><td>Lecture</td><td>2</td></tr>
<tr><td>2</td><td colspan="5">Study Content
• Introduction into nanoscience and nanotechnology
• Scanning force microscopy
• Scanning tunneling microscopy
• Scanning nearfield microscopy</td></tr>
<tr><td>3</td><td colspan="5">Learning Outcomes
The student is familiar with the basic concepts of nano- and microfabrication techniques. He/she has gained insights into contact mechanics and surface forces and is able to apply the appropriate model to a nanomechanical experiment. The students have achieved an extensive overview on established surface characterization techniques based on scanning probe microscopy including the physical principle, instrumentation, modes of operation and can explain underlying physical principles. The students can explain the interplay between manufacturing and evaluation/characterization in nanoscience. The students can analyze and explain physical phenomena at solid liquid interfaces. The students know how to select the adequate methods and to apply an appropriate but yet simple model to study nanophysical properties of soft and hard matter.</td></tr>
<tr><td>4</td><td colspan="5">Requirements for Participation
none</td></tr>
<tr><td>5</td><td colspan="5">Form of Examination
Final Module Examination:
• Module Examination (Technical Examination, oral / written Examination, Standard)</td></tr>
</table>

6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. B. Bhushan (Ed.), Handbook of Nanotechnology, Springer, Berlin Heidelberg, 2010. 2. E. Meyer, H. J. Hug, R. Bennewitz, Scanning Probe Microscopy, Springer, Berlin Heidelberg, 2004. 3. R. Garcia, Amplitude Modulation Atomic Force Microscopy, WILEY-VCH, Weinheim, 2010. 4. J. Israelachvili, Intermolecular & Surface Forces, Academic Press, London, 1992. 5. H.-J. Butt, M. Kappl, Surface and Interfacial Forces, WILEY-VCH, Weinheim, 2010.
10	**Comment** Cycle: each summer semester

Module Description

Module name

Scanning Transmission Electron Microscopy for Materials Science

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-9062	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Dr. rer. nat. Leopoldo Molina-Luna

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-9062-vl	Scanning Transmission Electron Microscopy for Materials Science	0	Lecture	2

2 Study Content

Electron probes of atomic dimensions are nowadays available in modern scanning transmission electron microscopes and make possible the efficient realization of incoherent imaging. The incoherent image uses high-angle scattering which leads to strong atomic

	number (Z) contrast and gives rise to "Z-contrast imaging". In the quest for higher resolution to understand the atomic origins of materials properties incoherent imaging appears to hold substantial advantages. This lecture will cover the (a) physical principles of incoherent imaging, (b) the electron Ronchigram, (c) instrumentation and alignment, (d) spherical aberration correction, (e) simulation and interpretation of Z-contrast images and (f) applications for nanostructure characterization and materials sciences.
3	**Learning Outcomes**
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, optional, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, optional, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** Scanning Transmission Electron Microscopy: Imaging and Analysis. Stephen J. Pennycook, Peter D. Nellist, Springer Aberration-corrected Analytical Electron Microscopy (RMS - Royal Microscopical Society). Rik Brydson Transmission Electron Microscopy: A Textbook for Materials Science. David B. Williams & C. Barry Carter
10	**Comment**

Module Description

Module name Semiconductor Interfaces					
Module no.	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester

11-01-8162					

Language of Instruction English	**Person responsible for the Module** Apl. Prof. Dr. rer. nat. Andreas Klein

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-8162-vl	Semiconductor Interfaces	0	Lecture	2

2 Study Content

- Carrier concentrations in semiconductors
- Excess carriers and carrier recombination
- Space charge layers
- Schottky diodes and p/n-junctions
- Charge transport characteristics of semiconductor diodes
- Solar cells, light emitting diodes, semiconductor lasers
- Barrier formation at semiconductor interfaces

3 Learning Outcomes

The student is able to remember the basic notions of semiconductor physics including carrier concentrations in thermal equilibrium and non-equilibrium situations. The student has the competence to develop energy band diagrams and understand the function of all basic semiconductor structures. He/she is qualified to evaluate semiconductor devices and remembers most important semiconductor materials, their properties and their use in current applications. The student is aware of several materials limitations of semiconductor devices.

4 Requirements for Participation

recommended: fundamentals of solid state physics

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)

8 Usability of the Module

	M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Klein, Semiconductor Interface, Lecture Notes (2009) 2. S.M. Sze, and K.K. Ng: Physics of Semiconductor Devices, John Wiley & Sons, Hoboken (2007) 3. P.Y. Yu, and M. Cardona: Fundamentals of Semiconductors. Physics and Materials Properties, Springer, Berlin (2001)
10	**Comment** Cycle: each winter semester

Module Description

Module name Seminar Metals					
Module no. 11-01-8211	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Apl. Prof. Dr.-Ing. Clemens Müller		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-8211-se	Seminar Metals	0	Seminar	2
2	**Study Content** Topics are given to elaborate on in a seminar talk. These topics are related to actual research in the field of metal alloys and their application. The seminar is designed to help to bridge the gap between the scientific education (textbooks) and scientific research (published papers). In the discussion section, students have to defend their seminar and should actively contribute to the discussion of other seminars.				
3	**Learning Outcomes** The student gains the ability to approach a scientific topic by accumulating information from textbooks and scientific literature. Ability to sort the information and present it to other students at a similar level of knowledge in a useful way. Learning to ask useful and the right questions to scientific talks. Drive to participate in discussion and drawing lines between different talks.				

4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Paper, Standard)
6	**Requirements on the Award of Credit Points** active participation in the seminar; successful seminar talk
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Paper, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** current research articles and advanced topics according to individual topics
10	**Comment** Cycle: each summer semester

Module Description

Module name

Seminar Research Topics in Materials Science

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-4055	2 CP	60 h	30 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Dr. rer. nat. Thomas Mayer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-4005-se	Seminar Research Topics in Materials Science	0	Seminar	2

2 Study Content

- Topics are given to elaborate on in a seminar talk. These topic are related to actual research areas in materials science. Each set of topics is coherent within a certain field of materials science. The seminar is designed to help to bridge the gap between the scientific

	education and textbooks and scientific reseach and published papers. • In the discussion section, students have to defend their seminar and should actively contribute to the discussion of other seminars. In the discussion the link between the talks should be reflected.
3	**Learning Outcomes** The student gains the ability to approach a scientific topic by accumulating information from textbooks and scientific literature. Ability to sort the information and present it to other students at a similar level of knowledge in a useful way. Learning to ask useful and the right questions to scientific talks. Drive to participate in discussion and drawing lines between different talks.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Paper, Standard)
6	**Requirements on the Award of Credit Points** active participation in the seminar; successful seminar talk
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Paper, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature**
10	**Comment** Cycle: each semester

Module Description

Module name Spintronics					
Module no. 11-01-2002	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction			**Person responsible for the Module**		

English	Prof. Dr. rer. nat. Lambert Alff

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2002-vl	Spintronics	0	Lecture	2

2 Study Content

- Introduction and basic notions of spintronics
- Spin dependent transport
- Magneto resistive (MR) effects, anisotropic magneto resistance (AMR)
- Giant magneto resistance (GMR)
- Spin dependent tunneling and tunneling magneto resistance (TMR)
- Materials for Spintronics, colossal magneto resistance (CMR)
- Spin transport in semiconductors
- Spintronic devices
- Meso and nanomagnetism
- Magnetic storage
- Selected (hot) topics from current research

3 Learning Outcomes

The student is able to adapt the concepts of spintronics to a broad range of situations and materials. The student has the competence to differentiate different types of magneto-resistive effects and their origin, and to correlate them with materials properties. He/she is qualified to evaluate experimental and theoretical methods for goal-oriented research in the area of spintronics. The student remembers modern spintronic materials and their use in current applications. The student has a first insight into modern research in spintronics and its device applications. He/she has a beginner's competence to follow advanced textbooks and scientific literature.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

passing of exam

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 1, Standard)

8 Usability of the Module

	M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. M. Ziese, M. J. Thornton (Eds.), Spin Electronics, Springer (2001) 2. D. D. Awschalom et al. (Eds.), Spin Electronics, Kluwer (2004) 3. S. Maekawa, Spin Electronics, Oxford University Press (2006) 4. S. Bandyopadhyay and M. Cahay, Introduction to Spintronics, Crc Pr Inc (2008) 5. L. Alff, Spintronics, Lecture Material (latest version 2010)
10	**Comment** Cycle: each summer semester

Module Description

Module name

Technology of Nanoobjects

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
11-01-2021	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Wolfgang Ensinger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-01-2021-vl	Technology of Nanoobjects	0	Lecture	2

2	**Study Content** Definitions of nanoobjects/-materials, Quantum mechanics basics, Classifications of nanoobjects, 1D nanostructures, Characterisation methods, Bioinspired materials, Catalysis with nanostructures, Nanomagnetism , Sensing technology
3	**Learning Outcomes** The student has gained an overview of classification of nanoobjects according to their dimensionality, with the emphasis on fabrication, characterization and application of one-dimensional nanoobjects, such as nanowires, -tubes, and networks thereof. The student obtained the competence to follow advanced literature in the field of nanotechnology based on one-dimensional nanoobjects.
4	**Requirements for Participation** none

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. P. Atkins, J. de Paula (2002). Atkin's Physical Chemistry. Oxford University Press, 7th edition. 2. M. Köhler, W. Fritzsche (2007). Nanotechnology: An Introduction to Nanostructuring Techniques. Wiley-VCH Verlag. 3. M. Schlesinger, M. Paunovic (2010). Modern Electroplating. John Wiley & Sons, 5th edition. 4. A. Eftekhari (2008). Nanostructured Materials in Electrochemistry. Wiley-VCH Verlag. 5. M. Vázquez (2015). Magnetic Nano- and Microwires. Woodhead Publishing. 6. J. M. D. Coey (2010). Magnetism and magnetic materials. Cambridge Univers. Press. 7. G. A. Ozin, A. C. Arsenault, L. Cademartiri (2009). Nanochemistry: a chemical approach to nanomaterials. RSC Publishing. 8. P. Gruber, D. Bruckner, C. Hellmich, H.-B. Schmiedmayer, H. Stachelberger, I. C. Gebeshuber (2011). Biomimetics -- Materials, Structures and Processes. Springer. Current scientific publications
10	**Comment** Cycle: each summer semester

Module Description

Module name Thermodynamics and Kinetics of Defects					
Module no. 11-01-3577	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Apl. Prof. Dr. rer. nat. Andreas Klein		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-3577-vl	Thermodynamics and Kinetics of Defects	0	Lecture	2

2	**Study Content** • Basic thermodynamics of solids • Thermodynamics of point defects • Defect reactions and concentrations • Kröger-Vink notation and Brouwer approximation • Boundary layers: Mott-Schottky and Guy-Chapman profiles • Diffusion processes • Chemical, electrical- and electrochemical potential gradients • Ambipolar diffusion and oxidation of metals
3	**Learning Outcomes** The student is able to remember the relevance of point defects for the electronic properties of materials. He/she has the competence to identify conditions under which point defects define material properties and to develop strategies how these can be modified. The student has a basic qualification to make materials selections for electronic and ionic applications.
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 1, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Klein, Thermodynamik und Kinetik von Punktdefekten, Lecture Notes (2006) 2. M.W. Barsoum, Fundamentals of Ceramics, IOP Publishing (2003) 3. J. Maier, Physical Chemistry of Ionic Materials, Wiley (2004)

10	**Comment** Cycle: each summer semester

Module Description

Module name Transmission Electron Microscopy (TEM)					
Module no. 11-02-6330	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 45 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Hans-Joachim Kleebe		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
11-02-2212-vu	Transmission Electron Microscopy (TEM)	0	Vorlesung und Übung	3

2 Study Content

- Conventional Transmission Electron Microscopy (TEM)
- Specimen Preparation
- Elements of the TEM (e.g., Lenses, Lens Aberrations)
- Electron Diffraction
- Bright Field and Dark Field Imaging Techniques
- Defects in Solids
- High-Resolution TEM
- Novel Developments in TEM (e.g., Cs- and Cc-Correctors)

3 Learning Outcomes

The student will be introduced to the operation of a modern transmission electron microscope (TEM), he/she will be familiar with the basic physical principals of TEM, he/she will be able to judge where this technique can be utilized and which limitations come with it, he/she will be introduced to a number of practical applications of TEM in material science and will be competent to evaluate experimental results obtained with this technique, the student will have obtained first insights in modern transmission electron microscopy and will be able to independently apply this knowledge for the continuation of her/his own experimental research in this area.

4 Requirements for Participation

Recommended: module “Introduction to Scanning Electron Microscopy”

5	**Form of Examination** Course Examination: • [11-02-2212-vu] (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points** Passing the exam
7	**Grading** Course Examination: • [11-02-2212-vu] (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature** 1. Transmission Electron Microscopy, D.B. Williams and C.B. Carter, (2nd Ed.) Springer Verlag (2009) 2. Introduction to Conventional Transmission Electron Microscopy, M. De Graef, Cambridge University Press (2003) 3. Principles of Analytical Electron Microscopy, J. Goldstein, D. C. Joy (Editor), A. D. Romig Jr., Springer Verlag (1986) 4. Electron Diffraction in the Electron Microscope, J.W. Edington, Macmillan (1975) 5. Electron Microdiffraction, J. C. H. Spence and J. M. Zuo, Springer Verlag, Berlin (1992) 6. Electron Beam Analysis of Materials, M. H. Loretto (2nd Ed.) Chapman & Hall (1994) 7. Electron Microscopy of Thin Crystals, P. B. Hirsch, A. Howie, R. B. Nicholson, D. W. Pashley and M. J. Whelan, Butterworths London (1965) 8. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, R. Egerton, Springer Verlag (2005) 9. Transmission Electron Microscopy: Physics of Image Formation and Microanalysis, L. Reimer, Springer New York (2009) 10. High-Resolution Transmission Electron Microscopy and Associated Techniques, P. Buseck, J. Cowley, L. Eyring, Oxford University Press (1988) 11. High-Resolution Electron Microscopy, J. C. H. Spence, Oxford University Press (2009)
10	**Comment** Cycle: each winter semester

Module Description

Module name					
Tunable properties in nanomaterials					
Module no. 11-01-2018	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. Ben Breitung		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	11-01-2018-vl	Tunable properties in nanomaterials	0	Lecture	2

2 Study Content

The conventional control of material properties is achieved by compositional (e.g. alloying) or microstructural modifications, such as variation of grain size, introduction of point (e.g. vacancies, dopant atoms), line (dislocations, twins) or planar (stacking faults) defects etc. This establishes microstructure-property relationships.

Going beyond these well-known concepts, the present course will introduce the idea and physics behind the reversible control of material properties, especially in surface-dominated nanomaterials. Among others, the electric potential as the control parameter will be discussed in greater detail; specifically, dielectric, ferroelectric and electrolytic gating concepts will be covered. At the next level, the course will introduce the notion that even surface and bulk chemistry can control material properties in a reversible manner. As selected case studies reversible modification of mechanical, magnetic and electrical properties in nanostructures of metals and semiconductors will be presented. At the end, the relationship of this property tuning with certain application areas will be addressed.

The lectures will be divided into the following topics:

Motivation
Physics of various gating principles
Nanomaterial synthesis and the optimization of their morphology
Field-effect controlled physical properties
Chemistry controlled physical properties

3 Learning Outcomes

4 Requirements for Participation

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** passing of exam
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Materials Science: Elective Courses Materials Science
9	**Literature**
10	**Comment** Cycle: each summer semester