C | A | U Christian-Albrechts-Universität zu Kiel Technische Fakultät

Institute for Materials Science

Master Course

Materials Science and Engineering

Course Guide

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Content

Compulsory Modules of the Master Course

Module number	**Mawi 701**
Module title	**Basic Laboratory Course for Master Students**
Module level	Deepening Materials Science
Abbreviation	BLC
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 1
Responsible institute	Institute for Materials Science
Responsible staff member	Dr. O. Riemenschneider
Lecturer	Head of Service Center and staff
Language	English
Assignment to the curriculum	Compulsory lab course in term 1 of the masters course “Materials Science and Engineering “
Teaching methods/SWS	2,5 SWS lab course
Work load	20 h preparation time (self-organized studies) 40 h lab course 60 h lab report writing (revision)
Credits	4
Prerequisites according to examination order	none
Recommended prerequisites	Knowledge of basics obtained during bachelors course
Learning outcome	Knowledge Practical expertise for Materials Science and Engineering, by means of instrumental measurement experiments. Skills Writing understandable and precise lab reports. Competences Working in a team with different backgrounds. Working accurately in a tight schedule.

Content	Hands-on experiments on selected topics in Materials Science and Engineering and related fields: M101 Evaporation Methods M102 Spin Coating M103 Nanostructuring of copper surfaces M104 Etching of Semiconductors M105 Micro Electromechanical Systems (MEMS) M106 Vibrating Sample Magnetometry (VSM) M107 Chemical Solution Deposition M108 Atomic Force Microscopy (AFM) M109 Scanning Electron Microscopy (SEM) M111 Biocompatibility Tests of Materials M212 Scanning Tunnel Mircoscope
Assessment of course achievements	Certificate after successful completion of laboratory
Media	Transmission and measurement equipment
Literature	Manuals are available for all experiments; they contain individual literature references for all experiments.

Module number	**Mawi 702**
Module title	**Solid State Physics**
Module level	Deepening Mathematics, Natural and Engineering Sciences
Abbreviation	SSP
Subtitle (if applicable)	
Courses (if applicable)	1) Solid State Physics Part 1 2) Solid State Physics Part 2
Study term	Term 1 and 2
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. F. Faupel
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Compulsory subject in term 1 and 2 of the masters course “Materials Science and Engineering“
Teaching methods / SWS	4 SWS lecture 2 SWS practical exercise
Work load	60 h lecture 30 h practical exercise 90 h self-organized studies 60 h revision
Credits	8
Prerequisites according to examination order	none
Recommended prerequisites	Basic in higher mathematics Basics in higher physics
Learning outcome	SSP Part 1 <u>Knowledge</u> After a brief introduction into fundamental quantum mechanics, the course treats the different types of chemical bonding, the resulting crystal structures and properties as well as lattice vibrations. <u>Skills</u> After the course the students will obtain a deeper understanding of the relationship between structure and thermal properties of solid materials. <u>Competences</u> They will be able to make corresponding calculations concerning on a higher level.

	SSP Part 2 <u>Knowledge</u> In the second part of the module, the focus is laid on the electronic structure and the resulting properties of solid martials The free electron model, energy bands in solids and the influence of external fields are discussed. <u>Skills</u> After the second part the students will be familiar with the thermal, electrical, magnetic, and dielectric properties of solids. <u>Competences</u> They will be able to make corresponding calculations concerning on a higher level.
Content	SSP Part 1 Quantum mechanical mathematical tools Quantum mechanical axioms and operators Schrödinger equation Chemical bondings Covalent bond Ionic bond Van der Waals bond Hydrogen bond Metallic bond Crystal structure Translational lattice Symmetry Simple crystal structures The effect of defects on physical properties Noncrystalline solids Diffraction by solids Crystalline solids and reciprocal lattice Structure factor Diffraction by noncrystalline solids Experimental methods Diffraction at surfaces Dynamics of crystal lattices Lattice vibrations Thermal expansion Thermal conduction by phonons Phonon spectroscopy SSP Part 2 Electrons in solids Free electron gas and Fermi statistics Specific heat of metals Thermionic emission of metals - Energy bands in solids Approximation of quasi free electrons Examples of band structures and density of states Influence of external fields Effective mass Hole concept Electrical conductivity of metals Thermoelectrical effects Contact potential

	Wiedemann-Franz law Semiconductors Intrinsic semiconductors Doping Experimental methods to determine electronic properties of semiconductors and metals Amorphous semiconductors p-n-junctions Heterostructures and super lattices Magnetic properties Diamagnetism, paramagnetism, ferro- and antiferromagnetism Dielectric properties Dielectric constant and polarizability Optical properties Ferroelectric solids Experimental methods to determine the dielectric function
Assessment of course achievements	During the semester exercises have to be submitted. During the examination period following the module "Solid State Physics II", a combined written exam (duration: 120 min.) on "Solid State Physics I and II" is held.
Media	Blackboard supplemented by excerpts of lecture notes presented on video projection Powerpoint / Slides (available in the internet)
Literature	• Ch. Kittel, Introduction to Solid State Physics, John Wiley & Sons, New York 1996 • H. Ibach and H. Lüth, Solid State Physics, Springer, New York 1995 • N.W. Ashcroft, N.D. Mermin, Solid State Physics, Saunders College Publishing, New York 1976

Module number	**Mawi 703**
Module title	**Thermodynamics and Kinetics**
Module level	Deepening Mathematics, Natural and Engineering Sciences
Abbreviation	TdK
Subtitle (if applicable)	
Courses (if applicable)	1) Thermodynamics and Kinetics Part 1 2) Thermodynamics and Kinetics Part 2
Semester	Term 1 and 2
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. L. Kienle
Lecturer	1) Prof. Dr. L. Kienle 2) Dr. J. Carstensen
Language	English
Assignment to the curriculum	Compulsory subject in term 1 and 2 of the masters course “Materials Science and Engineering“
Teaching method / SWS:	4 SWS lecture 2 SWS practical exercise
Work load	60 h lecture 30 h practical exercise 90 h self-organized studies 60 h revision
Credits	8
Prerequisites according to examination order	none
Recommended prerequisites	Basic lecture mathematics Basic lecture physics Basic lecture chemistry
Learning outcome	Knowledge The lecture provides an in-depth understanding of thermodynamics and kinetics for material scientists. The lecture demonstrates the function of model systems, e.g. perfect gas, ideal solution etc. for the calculation of the materials properties. Modifications of the simple models represent a more realistic point of view, thus enabling the description of real systems Skills The lecture provides knowledge in practical fields, e.g. how the properties of materials and their technological application are related to their thermodynamic properties. Examples for

	essential industrial products and processes are discussed in conjunction with their thermodynamic aspects. Competences The students learn to combine their skills in mathematics, physics and chemistry to the interdisciplinary aspects of thermodynamics and kinetics.
Content	Basic properties of gases Model of the perfect gas Models for real gases Quantitative interrelations of the models Reduced variables and corresponding states The First Law Theory of state functions Heat and work Theory of heat capacity Enthalpy Joule- and Joule-Thomson experiment The Second Law Heat engines Entropy and spontaneity of processes Gibbs- and Helmholtz energies Chemical potential of real systems, fugacity and activity Physical transformations of pure substances Phase rule of Gibbs Simple phase diagrams (pVT-plots) Clapeyron's equation and its application to phase diagrams Ehrenfest classification Lambda transitions Phase Change Materials (PCM) High Performance Ceramics Simple mixtures Ideal vs. real mixture Entropy of mixing, excess enthalpies Partial molar quantities- theory and application Ideal and ideal dilute solutions Raoult's, Henry's law and deviations Activities of solutions Activity coefficients (Debye-Hückel theory) Phase diagrams Calculation of phase diagrams Practical aspects of binary and ternary phase diagrams Chemical equilibrium Equilibrium conditions Response of equilibriums to conditions Chemical vapor transport of solids Ellingham diagrams Molecules in motion Kinetic model of gases Distribution of speeds Simple collision theory Theory of transport phenomena Chemical kinetics Rate laws

	Theory of unimolecular reactions Advanced collision theory Diffusion and activation control of chemical kinetics Potential energy surfaces Statistical thermodynamics Distribution and partition function Examples for statistical approaches Statistics and polymers Calculation of state functions Equations of state Chemistry and statistics Irreversible thermodynamics Production of entropy Forces and fluxes Onsager theorem Linear and non-linear processes
Assessment of course achievements	During the semester exercises have to be submitted. During the examination period following part 1 and part 2, a written exam (duration: 120 min.) is held.
Media	Powerpoint, Excel and others
Literature	• P. Atkins, Physical Chemistry, 8th ed, Oxford 2006 • Balluffi et al. Kinetics of Materials, Wiley 2004 • David R. Gaskell, Introduction to the Thermodynamics of Materials, Taylor & Francis, New York 2003 • H. Weingärtner: Chemische Thermodynamik, Teubner 2003 • B. S. Bokstein, M. I. Mendelev, D. J. Srolovoitz: Thermodynamics & Kinetics in Materials Science, Oxford University Press 2003

Module number	**Mawi 704**
Module title	**Analytics**
Module level	Deepening Materials Science
Abbreviation	An
Subtitle (if applicable)	
Courses (if applicable)	1) Analytics Part 1 2) Analytics Part 2
Study term	Term 1 and 2
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. E. Quandt
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Compulsory subject in term 1 and 2 of the masters course “Materials science and Engineering“
Teaching methods / SWS	4 SWS lecture 2 SWS practical exercise
Work load	60 h lecture 30 h practical exercise 90 h self-organized studies 60 h revision
Credits	8
Prerequisites according to examination order	none
Recommended prerequisites	Basic lecture mathematics Basic lecture physics Basic lecture chemistry
Learning outcome	Knowledge The lecture course aims at providing a deep understanding of advanced analytical techniques. Skills The student will know the major methods with their potentials and limitations, can interpret results in a general way. Competences The Students are particularly capable of assessing what kind of analytical tool or combination of tools can serve his future need while pursuing a career in Materials Science and Engineering.

Content	Overview over particle beam- and radiation methods for the analysis of interfaces and thin films Scanning electron microscopy (SEM) Transmission electron microscopy (TEM) Ion backscattering methods Secondary ion mass spectroscopy Overview over methods for analysis of surfaces and interfaces Electron emission spectroscopy methods Scanning probe microscopy X-ray methods
Assessment of course achievements	During the semester the students give presentations about the topics of the course. During the examination period following the module "Analytics II", a combined oral exam (duration: 20-30 min.) on "Analytics I and II" is held.
Media	Lecture notes Foils Blackboard Laptop presentations (available in the internet)
Literature	• J.M. Walls (Ed.): Methods of Surface Analysis; Cambridge University Press 1989 • E. Fuchs, H. Oppolzer, H. Rehme: Particle Beam Microanalysis - Fundamentals, Methods and Applications; VCH 1990 • R. Brundle, C.A. Evans Jr., S. Wilson (Eds.): Encyclopedia of Materials Characterization; Butterworth-Heinemann 1992 • Materials Science and Technology (Eds. R.W. Cahn, P. Haasen, E.J. Kramer): Vol.2 Characterization of Materials VCH 1992

Module number	**Mawi 705**
Module title	**Advanced Materials A**
Module level	Deepening Materials Science
Abbreviation	AMA
Subtitle (if applicable)	
Courses (if applicable)	1) Advanced Materials A - Metals 2) Advanced Materials A - Polymers
Study term	Term 1
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. F. Faupel
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Compulsory subject in term 1 of the masters course “Materials Science and Engineering“
Teaching methods / SWS	4 SWS lecture 2 SWS practical exercise
Work load	60 h lecture 30 h practical exercise 90 h self-organized studies 60 h revision
Credits	8
Prerequisites according to examination order	none
Recommended prerequisites	Basic lecture mathematics Basic lecture physics Basic lecture chemistry
Learning outcome	<u>Knowledge</u> The module aims at making the students familiar with the relation between structure and resulting properties of metallic and organic materials. Emphasis will be placed on mechanical properties. <u>Skills</u> The students will learn how to apply their knowledge on basic materials science and on solid state physics to understanding the design of advanced metallic and organic materials. <u>Competences</u> The students will be able to understand the current literature on metallic and organic materials and to deal with them in research, development, and production.

Content	Metals Alloys Thermodynamic considerations Intermetallic phases Mechanical Properties Plastic deformation in single crystals via dislocations Deformation twinning Deformation of polycrystals Creep Fracture Solid solution hardening Thermally Activated Processes Diffusion Recrystallization Solidification of Metallic Melts Transformation in the Solid State Particle Hardened Alloys Polymers Properties and Classification of Plastics Binding Forces and Structure Polymer Synthesis Polymers in Melts and Solutions Thermodynamics and chain kinetics Crystallization and Glass Formation Mechanical Properties Dielectric and Optical Properties Conducting Polymers Sorption, Diffusion and Permeation Chemical and Physical Aging, Recycling Plastics technology
Assessment of course achievements	During the lecture period, exercises should be submitted weekly. During the examination period following the module, a written exam (duration: 120 min.) on both topics is held.
Media	Lecture notes Foils Blackboard Laptop presentations (available in the internet)
Literature	• P. Haasen, Physical Metallurgy, Cambridge University Press, Cambridge 1996 (German edition available) • K. Easterling, Modern Physical Metallurgy, Butterworths 1983 • Cottrell, An Introduction to Metallurgy, The Institute of Metals 1995 (reprint at 1975 edition) • N. Stoloff, Physical Metallurgy and Processing, Chapman 1994 • G. Gottstein, Physikalische Grundlagen der Materialkunde, Springer 1998 (German) • H. Böhm, Einführung in die Metallkunde, B. I. 1992 (German)

	• E. Hornbogen und H. Warlimont, Einführung in die Metallkunde, Springer 1991 (German) • R.E. Reed-Hill and R. Abbaschian, Physical Metallurgy Principles, PWS-Kent 1992 • R.E. Smallman and R.J. Bishop, Modern Physical Metallurgy of Materials Engineering, Butterworth/Heinemann/1999 • R. Cahn und P. Haasen (Eds.), Physical Metallurgy, Elsevier Science 1996 • R.J. Young, P.A. Lovell: Introduction to Polymers, Chapman & Hall 1991. • L.H. Sperling: Introduction to Physical Polymer Science, John Wiley 1992. • U. Eisele: Introduction to Polymer Physics, Springer 1990. • N.G. McCrum, C.P. Buckley, C.B. Bucknall, Principles of Polymer Engineering, Oxford Science Publications 1995. • G. Menges: Werkstoffkunde Kunststoffe, Hanser 1990 (German) • G. W. Ehrenstein: Polymerwerkstoffe, Hanser 1978 (German) • W. Retting, H.M.Laun: Kunststoffphysik, Hanser 1991 (German).

Module number	**Mawi 706**
Module title	**Advanced Materials B**
Module level	Deepening Materials Science
Abbreviation	AMB
Subtitle (if applicable)	
Courses (if applicable)	1) Advanced Materials B - Electronic Materials 2) Advanced Materials B - Ceramics
Study term	Term 2
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. J. McCord
Lecturer	Professors and staff
Language	English
Assignment to the curriculum	Compulsory subject in term 1 of the masters course “Materials Science and Engineering“
Teaching methods / SWS	4 SWS lecture 2 SWS practical exercise
Work load	60 h lecture 30 h practical exercise 90 h self-organized studies 60 h revision
Credits	8
Prerequisites according to examination order	none
Recommended prerequisites	Basics materials science Basics in semiconductors technology Basics in advanced mathematics
Learning outcome	<u>Knowledge</u> Students will understand the abundance of electronic materials spanning the range from semiconductors to ceramics and including “simple” topics like conductors and magnetic materials. <u>Skills</u> They will learn that technology is intimately linked to properties and functions and apply this knowledge to the functions and the making of devices like Si chips, sensors, solar cells, thermoelectric, magnetic and nano compound devices. <u>Competences</u>

	Students will get a solid background in general theory which enables them to quickly adapt to new materials, concepts and devices that will come up in the future. Students will be able to assume positions in R&D and production of electronic devices at all levels with a minimum of on-the-job learning time.
Content	Electronic Materials Conductors Ionic conductors and their applications Thermoelectricity Transparent conductors. Theory of dielectrics Polarization mechanisms Frequency behaviour Complex dielectric function Complex index of refraction Ferroelectricity. Basic optics Fresnel equations Complex index of refraction and optical properties, Optical communication Lasers and optical modes. Theory of magnetism Dia-, para- and ferromagnetism Mean field theory of ferromagnetism Domain structure Hysteresis. Fundamentals of semiconductor processing Single crystal growth Essential processes and limitations Ceramics Ceramics processing Bulk and thin film techniques Sintering, sputtering and other processing Microstructure Mechanical and thermal properties Ferroelectric Piezoelectric Electrooptic materials Pyroelectrical behaviour Ceramic conductors Ceramic superconductors Magnetic and magnetoelectric ceramics and nanocompounds
Assessment of course achievements	During the lecture period, exercises can be submitted weekly. During the examination period following the module, a written exam (duration: 120 min.) on “Electronic Materials” is held.
Media	Lecture notes Foils

	Blackboard Laptop presentations
Literature	• L.A.A. Warnes: Electronic Materials • R.E. Hummel: Electronic Properties of Materials • Kingery, W.D., Bowen, H.K., Uhlmann, D.R.: Introduction to Ceramics, Wiley-Interscience, New York • Moulson, A.J., Herbert, J. M.: Electroceramics (Materials, Properties, Applications); Chapman & Hall, London • Steele, B.C. H. (Hrsg.): Electronic Ceramics; Elsevier Applied Science, London • Schaumburg, H. (Hrsg.): Keramik; B.G. Teubner, Stuttgart • Hench, L.L., West, J.K.: Principles of Electronic Ceramics; Wiley-Interscience, New York • Internet Script: http://www.tf.uni-kiel.de/matwis/amat/elmat_en/index.html

Module number	**Mawi 707**
Module title	**Advanced Mathematics**
Module level	Deepening Mathematics, Natural and Engineering Sciences
Abbreviation	AMAT
Subtitle (if applicable)	
Courses (if applicable)	1) Mathematics for Material Science 2) Computational Mathematics
Study term	Term 1
Responsible Institute	Institute for Materials Science
Responsible Staff Member	Dr. J. Carstensen
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Compulsory subject in term 1 of the masters course “Materials Science and Engineering“
Teaching Methods / SWS	Mathematics for Material Science: 2 SWS lecture 1 SWS practical exercises Computational Mathematics: 1 SWS lecture 1 SWS practical exercises
Work load	45 h lecture 30 h practical exercise 60 h self-organized studies 45 h revision
Credits	6
Prerequisites according to examination order	none
Recommended prerequisites	Basics in mathematics
Learning outcome	<u>Knowledge</u> The lecture provides a robust "toolbox" for solving mathematical problems in material science analytically and numerically. <u>Skills</u> Students should be able to write programs in Mathlab for visualizing results in 2D and 3D, analyse measured data and solve transcendent equations and differential equations. Team work in the programming part will improve the social skills of the students. <u>Competences</u>

	The students get a reasonable theoretical mathematical background and a basic understanding of numerical algorithms for an efficient use of computers.
Content	Mathematics for Material Science Algebra - Complex numbers - Complex e-function - Other complex functions - Vectors in N-dimensional space - Matrices - Square matrices and determinants - Systems of Linear Equations - Eigenvalues and Eigenvectors - Scalar and vector product - Hermite and unitary matrices with complex components Calculus I: Functions of one Variable - Derivatives and Integrals - Calculation rules of derivatives and integrals - Sequences and Series - Taylor series and their application - Linear Optimization - Fitting to an orthonormal set of functions - Functions as vectors - Schmidt's orthonormalization procedure - Fourier series - Fourier-Transforms - Solution of DEQs by Fourier Transformation - Fourier Series vs. Fourier Transformation - Error function - Gamma function - Delta function Calculus II: Functions of multiple variables - Partial derivatives / Derivatives in certain directions - Total Derivatives - Minimization problems - Simple N-dimensional integrals Computational Mathematics General programming - The program Matlab - Variables - Functions - Algorithms - Representation of numbers in computers - Numerical errors Data Visualization - Curves, Histograms, log-scale - 2D - 3D Interpolation - Polynomial interpolation - Cubic spline

	Finding Zeros - Iterative Methods - Fix Points - Bisectioning - Newton algorithm Numerical Minimization - Linear optimization - Nonlinear optimization - Golden section search - Fitting of data Solving linear systems of equation - Gaußian algorithm - Pivotization Numerical integration - Trapezium rule - Simpson rule - Higher order rules Integration of ordinary differential equations - Euler method - Runge-Kutta method - Stiff sets of differential equations - Implicit algorithms
Assessment of course achievements	Written solutions of exercises, short summary of (2 student) team work in computational mathematics are requirements for participation in examination. During the examination period following the module, a written exam (duration: 120 min.) on “Advanced Mathematics” is held.
Media	Powerpoint, MATLAB
Literature	Mathematics for Material Science • Script for "Mathematics for Material Science" • Engineering mathematics: a foundation for electronic, electrical, communications and systems engineers, Anthony Croft. - 3. ed. - Harlow, England [u.a.] : Prentice Hall, 2001 • Basic mathematics for electronic engineers: models and applications, John E. Szymanski. - London : Van Nostrand Reinhold, 1989 • Modern engineering mathematics, Glyn James. - 3rd ed. - Harlow [u.a.] : Prentice Hall, 2001 • Advanced modern engineering mathematics, Glyn James. - 2. ed. - Harlow, England [u.a.] : Addison-Wesley, 1999 Computational Mathematics • Script for " Computational Mathematics" • Numerical methods in engineering with MATLAB, Jaan Kiusalaas. - Cambridge [England] : Cambridge University Press, 2005 (auch E-book) • MATLAB for engineers explained, Fredrik Gustafsson. - 2. pr. - London [u.a.] : Springer, 2003 • Getting started with MATLAB 7: a quick introduction for scientists and engineers, Rudra Pratap. - New York [u.a.] : Oxford Univ. Press, 2006

	• Numerical recipes in C: the art of scientific computing, William H. Press. - 2. ed.. - Cambridge [u.a.] : Cambridge Univ. Press, 1992

Module number	**Mawi 801**
Module title	**Advanced Laboratory Course for Master Students**
Module level	Deepening Materials Science
Abbreviation	ALC
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 2
Responsible institute	Institute for Materials Science
Responsible staff member	Dr. O. Riemenschneider
Lecturer	Head of Service Center and staff
Language	English
Assignment to the curriculum	Compulsory lab course in the term 2 of the masters course “Materials Science and Engineering “
Teaching methods / SWS	3 SWS lab course
Work load	30 h preparation time (self-organized studies) 45 h lab course 75 h lab report writing (revision)
Credits	5
Prerequisites according to examination order	none
Recommended prerequisites	Knowledge of basics obtained during basic lab course
Learning outcome	Knowledge Practical expertise for Materials Science and Engineering, by means of instrumental-measurement experiments. Skills Working in a team with different backgrounds. Working accurately in a tight schedule. Competences Writing understandable and precise lab reports.

Content	Hands-on experiments on selected topics in Materials Science and Engineering and related fields: M201 Shape Memory Alloys M202 Sorption and Diffusion in Membranes M203 Photocatalysis M204 Cantilever Deflection Method M205 Magnetostrictive Materials M206 Tunneling Magneto Resistance M207 Heterostructure Lasers M208 Impedance Spectroscopy M209 MOKE Microscopy M210 X-Ray Photoelectron Spectroscopy M211 Dynamic Mechanical Analysis of Polymers
Assessment of course achievements	Certificate after successful completion of laboratory
Media	Transmission and measurement equipment
Literature	During the lab course, a set of references is given for each experiment. Manuals are available for all experiments; they contain individual literature references for all experiments.

Regular offered
Technical Elective Modules
of the Master Course

Module number	**Mawi 903**
Module title	**Electron Microscopy**
Module level	Deepening Materials Science
Abbreviation	ELM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. L. Kienle
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	3 SWS lecture 2 SWS e practical xercise
Work load	45 h lecture 30 h practical exercise 60 h self-organized studies 45 h revision
Credits	6
Prerequisites according to examination order	none
Recommended prerequisites	Basic lecture in physics
Learning outcome	<u>Knowledge</u> The module covers the relevant methods of electron microscopy for the characterization of inorganic solids. <u>Skills</u> Students will gain profound insights into the application of electron microscopy in the field of materials science and will be capable of understanding electron microscopy in depth. <u>Competences</u> Students will be ready to specialize in this topic. In the exercise students will work in small teams improving their competence in teamwork.
Content	Introduction to TEM and SEM Hardware Imaging, Diffraction, Spectroscopy

	Electron crystallography Theory of domain crystals Advanced analytical techniques Characterization of magnetic structure EM in Material Science In situ observations TEM on nanomaterials Real structure and diffuse scattering Crystal defects, e.g. twinning Combined approach for structure analysis
Assessment of course achievements	During the examination period following the module, an oral exam (duration: 30 min.) on “Electron Microscopy” is held.
Media	Lecture notes Foils Blackboard Laptop presentations
Literature	• Williams, C. B. Carter : Transmission Electron Microscopy- A Textbook for Materials Science 2nd Edition Springer 2009 • L. Reimer, H. Kohl: Transmission Electron Microscopy: Physics of Image Formation, Springer 2009

Module number	**Mawi 904**
Module title	**Micro/Nano Systems Technology and Processes**
Module level	Deepening Materials Science
Abbreviation	MNT
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science Fraunhofer Institute for Silicon Technology
Responsible staff member	Prof. Dr. E. Quandt Prof. Dr. B. Wagner
Lecturer	Professors and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods / SWS	4 SWS lecture 2 SWS practical exercise
Work load	60 h lecture 30 h practical exercise 30 h self-organized studies 60 h revision
Credits	6
Prerequisites according to examination order	none
Recommended prerequisites	Basics in solid state physics Basics in materials science Basics in optics
Learning outcome	Knowledge Students will be introduced to actual clean room processes and techniques in practice. Skills Students will get a deeper and better understanding of clean room work. Moreover the students will learn about safety and specific cleanroom regulations. Competences Students will be able to bridge from lab course to production environment.
Content	Introduction to micro- and nanosystems technology Cleanroom technology Optical and electron beam lithography

	Thin film deposition: PECVD, sputtering, evaporation, pulse laser deposition Wet and dry etching Optical and scanning electron microscope inspection MEMS materials MEMS technologies Doping of silicon Micromechanical sensors Piezoelectric transducers Thermal sensors and actuators MOEMS MEMS packaging
Assessment of course achievements	During the examination period following the module, a written exam (duration 120 min) on “Micro/Nano Systems Technology and Processes” is held.
Media	Lecture notes Foils Blackboard Laptop presentations
Literature	• Marc J. Madou, Fundamentals of microfabrication: the science of miniaturization, CRC Press, 2002 • J. Plummer, M. Deal, P. Griffin, Silicon VLSI technology, Prentice Hall 2000 • M.A. McCord, M.J. Rooks, Handbook of Microlithography, Micromachining and Microfabrication – Vol 1, SPIE Optical Engineering Press, 1997 • P. Rai-Choudhury, Handbook of microlithography, micromachining, and microfabrication – Vol 2, SPIE Optical Engineering Press [u.a.], 1997 • Chang Liu, Foundations of MEMS, Pearson Education, New Jersey, 2006 • Sergey E. Lyshevski, MEMS and NEMS: Systems, Devices, and Structures, Series: Nano- and Microscience, Engineering, Technology and Medicine Volume: 2, CRC Press, New York, 2002

Module number	**Mawi 905**
Module title	**Nanochemistry for Nanoengineering**
Module level	Deepening Materials Science
Abbreviation	NCN
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. Mady Elbhari
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course “Materials Science and Engineering“
Teaching methods / SWS	2 SWS lecture 1 SWS practical exercise
Work load	30 h lecture 15 h practical exercise 45 h self-organized studies 30 h revision
Credits	4
Prerequisites according to examination order	none
Recommended prerequisites	Basics in chemistry Basics in nanotechnology
Learning outcome	<u>Knowledge</u> Students will learn the nanoscale paradigm in terms of properties at the nanoscale dimension as well as the history of nanotechnology and where the field may evolve over the next years. <u>Skills</u> Students will be able to apply key concepts in materials science, chemistry, physics, biology and engineering to the field of nanotechnology. <u>Competences</u> Students will learn to identify current nanotechnology solutions in design, engineering and manufacturing.
Content	Emergence of the fields State of the Art and Challenges

	Surface Science and Surface energy Nanochemistry Dimensionality and Materials Nanosynthesis Homogenous and Heterogeneous Nucleation Sol-Gel-Synthesis Forced hydrolysis Solid state phase segregation Kinetically confined synthesis Seeding Micelles and micro emulsion Aerosol Spray Pyrolysis Microwave Template-based synthesis Carbon Fullerenes and Nanotubes Micro and Mesoporous Core-shell structures Organic/Inorganic hybrids Nanocomposite Intercalation Green Nanosynthesis Nanopatterning Self-assembly and self-organization Capillary forces Dispersion Interaction Shear force assisted assembly Electric field assisted assembly Covalently linked assembly Template assisted assembly Green Nanopatterning Nanoengineering
Assessment of course achievements	During the examination period following the module, a written exam (duration: 120 min.) on “Nanochemistry and Nanoengineering” is held.
Media	Lecture notes Foils Blackboard Laptop presentations
Literature	• G. Cao, Nanostructures and Nanomaterials: Synthesis, Properties & Applications, World Scientific Publishing Co, Singapore, 2010. • G. A. Ozin, A. C. Arsenault, L. Cademartiri , Nanochemistry: A Chemical Approach to Nanomaterials , Springer Verlag, Berlin, 2008.

Module number	**Mawi 907**
Module title	**Semiconductors**
Module level	Advanced Materials Science
Abbreviation	SC
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. R. Adelung
Lecturer(s)	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching Methods / SWS	2 SWS lecture 1 SWS practical exercises
Work load	30 h lecture 15 practical exercise 45 h self-organized studies 30 h revision
Credits	4
Prerequisites according to examination order	none
Recommended prerequisites	Lecture Advanced Mathematics Basic in semiconductor theory Basics in silicon technology Basics in thin film technology
Learning outcome	<u>Knowledge</u> The module aims at providing the essentials of semiconductor physics and technology with emphasize on semiconductors other than Si, important products, and key technologies. <u>Skills</u> Thorough understanding of semiconductor physics. From the free electron gas to topics like Shockley-Read-Hall theory, advanced junction theory or quantitative Laser conditions. Good understanding of various semiconductors in terms of properties and limits.

	Thorough understanding of the basics of LED's and semiconductor Lasers plus a deeper insight into some selected specialities. Basic knowledge of some special semiconductors (e. g. organic semiconductors, selected II-VI's, or SiC). <u>Competences</u> Stundents will be able to understand the rapid advances of semiconductor products and technology within a framework consisting of theory, specific material properties and limitations, and available technology. They will emerge with a broad competence in dealing with the specific physical semiconductor culture (including the "slang") and will be able to deal with the mathematics, often encountered in the form of rather long equations because they understand the underlying basic principles. They will be ready to assume suitable engineering positions in the industry with a minimum of introductory time.
Content	Band theory Essentials of the Free Electron Gas; Energy Gaps and General Band Structure; Periodic Potentials and Bloch's Theorem; Band Structures and Standard Representations. Semiconductor physics Intrinsic properties in equilibrium; Doping, carrier concentration, mobility, and conductivity; Lifetime and diffusion length; Effective masses; Quasi Fermi energies; Shockley-Read-Hall recombination; Junctions and devices. Fundamentals of optoelectronics Materials and radiant recombination; Recombination and luminescence; Doping of compound semiconductors; Wavelength engineering; Light and semiconductors; Total efficiency of light generation; Absorption and emission of light. Heterojunctions Ideal heterojunctions; Isotype junctions, modulation doping, and quantum effects; Real heterojunctions; Quantum devices; Single and multiple quantum wells. Principles of the semiconductor LASER LASER conditions; Interaction of light and electrons and inversion; Light amplification in semiconductors; From amplification to oscillation; Second Laser condition; Laser modes. Light emitting devices Basic requirements and design principles; Products, market, materials, and technologies; Selected LED concepts; Optimizing light confinement and gain in Laser diodes; Double heterojunctions; Key technologies. Special Semiconductor Siliconcarbide, Materials aspects and applications; Galliumnitride; II - VI Semiconductors; Semiconducting polymers.
Assessment of course achievements	Exercises are seminar-styled. Student groups (2-3) present a specified topic and write it down in a formalized way (paper as in conference proceedings)

Media	Beamer, for illustrations and simulations Blackboard.
Literature	Complete interactive Internet script http://www.tf.uni- kiel.de/matwis/amat/semi_en/index.html Selected text books for special topics given in script

Module number	**Mawi 909**
Module title	**Smart Materials**
Module level	Deepening Materials Science
Abbreviation	SM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. E. Quandt
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods / SWS	2 SWS lecture 1 SWS practical exercise
Work load	30 h lecture 15 h practical exercise 45 h self-organized studies 30 h revision
Credits	4
Prerequisites according to examination order	none
Recommended prerequisites	Basics in solid state physics Basics in materials science
Learning outcome	<u>Knowledge</u> The students will be introduced into the domain of smart materials. <u>Skills</u> The students will understand the correlation between composition, microstructure and properties of smart and multiferroic materials. <u>Competences</u> Students will get a compendium over smart materials for understanding new approaches to materials sciences problems. The students will have learned scientific purchase as well as bulk fabrication rules.
Content	Smart Materials

	- Classification - Application Areas Piezoelectric Materials - Piezoeffect - Piezoelectric Materials - Ferroelectricity - Fabrication - Applications Magnetostrictive Materials - Magnetostriction - Cryogenic Materials - Rare Earth - Fe phases - Thin Film Materials - Applications Shape Memory Alloys - Shape Memory Effects - Superelasticity - TiNi - based materials - Shape Memory Thin Films - Applications Multiferroic Materials - Magnetic Shape Memory Materials - Magnetoelectric Composites
Assessment of course achievements	During the examination period following the module, a written exam (duration: 120 min.) on “Smart Materials” is held.
Media	Lecture notes Foils Blackboard Laptop presentations
Literature	• K. Uchino, Ferroelectric Devices, New York: Marcel Dekker, 2000 • Giant magnetostrictive materials: physics and device applications, Ed: G. Engdahl. San Diego: Academic Press, 2000 • C. M. Wayman und K. Otsuka, Shape Memory Materials, Cambridge University Press, 1999

Module Number	**Mawi 928**
Module title	**Solid State Chemistry and Crystallography**
Module level	Deepening Materials Science
Abbreviation	SSC
Subtitle (if applicable)	
Courses (if applicable)	
Semester	Term 4
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. L. Kienle
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 4 of the masters course "Materials Science and Engineering"
Teaching method / SWS	2 SWS lecture 1 SWS practical exercise
Work load	30 h lecture 15 h practical exercise 45 h self-organized studies 30 h revision
Credits	6
Prerequisites according to examination order	none
Recommended prerequisites	Basics in chemistry Basics in solid state physics
Learning outcome	<u>Knowledge</u> The lecture conveys an understanding of real structure-property relations following the classical approach of solid state chemistry. <u>Skills</u> Advanced features of solid bulk materials are discussed (including structural theory) by selected examples of technically applied materials. <u>Competences</u> Students are enabled to understand the structure and application of state of the art functional bulk materials.
Content	Structure of complex materials - Crystallography - Structure determination of bulk materials

	- Intermetallic phases - biomaterials - porous materials - silicates - metal organic frameworks Real structure of solids - Disorder of bulk materials - Theory of real structures with crystallographic group theory - Experimental characterization of disordered materials Preparative methods for bulk materials - Solid state reactions - Formation of solids from the gas phase - Formation of solids from melts - Preparation of inorganic polymers - Porous and nanostructured materials
Examination	During the examination period following the module, a written exam (duration: 120 min.) on “Solid State Chemistry” is held.
Media	Powerpoint and others
Literature	• Doughlas, McDaniel, Alexander, Concepts and Models of Inorganic Chemistry, Wiley, 1992 • Shriver, Atkins, Inorganic Chemistry (3rd ed, 1999) • W.H. Freeman and Company (Chs. 3, 18 ...) • L. Smart, E. Moore, Solid State Chemistry, 2nd Ed. Chapman & Hall, London, 1995 • P.A. Cox, The Electronic Structure and Chemistry of Solids, Oxford University Press, 1987 • U. Müller, Inorganic Structural Chemistry Wiley, Chichester, 1993 • A.R. West, Solid State Chemistry and its Applications, Wiley, New York, 1984

Module number	**Mawi 911**
Module title	**Thin Films**
Module level	Deepening Materials Science
Abbreviation	TF
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science
Responsible staff member	Prof. Dr. K. Rätzke
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods / SWS	3 SWS lecture 2 SWS practical exercise
Work load	45 h lecture 30 h practical exercise 60 h practical exercise self-organized studies 45 h revision
Credits	6
Prerequisites according to examination order	none
Recommended prerequisites	Lecture Advanced Materials A Lecture Analytics
Learning outcome	<u>Knowledge</u> Deposition methods (PVD, CVD etc.), nucleation and growth of thin films, microstructure, characterization methods including application and limits. Properties of thin films (mechanic, magnetic etc) as function of microstructure. <u>Skills</u> The students will understand preparation methods of thin films, correlation of preparation conditions, microstructure and properties. They will further understand measurement methods for characterization of thin films. <u>Competences</u> By combination of lecture, pre- and post processing, literature studies and internet research they practicing different strategies of knowledge acquisition.

	Social competence and research methods will be developed during continuous interactive process during course with active participation of students. With permanent orientation on recent problems the aim is to increase activity of students to solve problems and to apply theoretical models to real problems and therefore lead to a smooth transition from passive participation to active research and technology applications.
Content	Vacuum physics Deposition methods Properties of Thin Films Thin film growth characterization Epitaxy Microstructural evolution Interdiffusion Reactive diffusion Mechanical properties Electrical, magnetic and optical properties
Assessment of course achievements	During the examination period following the module, a written exam (duration: 120 min.) on “Thin Films” is held.
Media	Power Point presentation Blackboard
Literature	• M. Ohring, The Materials Science of Thin films, Academic Press, 1992, 2000 2nd edition • D.L. Smith, Thin Film Deposition, McGraw Hill, 1995 • K.N. Tu et al. Electronic Thin Film Science, Macmillan, 1992 • R.C. O'Handley, Modern Magnetic Materials, Wiley, 2000

Module number	**Mawi 931**
Module title	**Selected Topics in Materials Science**
Module level	Deepening Materials Science
Abbreviation	STMS
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible institute	Institute for Materials Science
Responsible staff member	Dr. O. Riemenschneider
Lecturer	Professors of the Institute and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods / SWS	1 SWS seminar
Work load	15 h seminar 75 h self-organized studies
Credits	3
Prerequisites according to examination order	none
Recommended prerequisites	Deepened knowledge in Materials Science
Learning outcome	Knowledge By literature work of actual topics the students get a closer contact an impression of the on-going research in materials science. Skills The students will understand literature work and online research in science topics. The will extend their knowledge in presenting new topics to professional audience. Competences By literature studies and internet research the students practise a fundamental strategie of knowledge acquisition. Social competence and research methods will be developed during course with active participation of students.
Content	Every student will get a topic of actual research which she/he has to work on. They will be coached by one responsible professor.

Assessment of course achievements	During the semester a talk has to be worked out and presented at the end of the term.
Media	Power Point Presentation Blackboard
Literature	• *Given by the responsible professor.*

Alternating offered
Technical Elective Modules
of the Master Course

Module number	**Mawi 913**
Module title	**Cell Mechanics**
Module level	Deepening Materials Science
Abbreviation	CM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. C. Selhuber
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course “Materials Science and Engineering“
Teaching methods/SWS	2 SWS lecture 2 SWS practical exercise
Work load	30 h lecture 30 h practical exercise 45 h self-organized studies 45 h revision
Credits	5
Prerequisites according to examination order	none
Recommended Prerequisites	Knowledge in Mathematics and Mechanics from Bachelor courses
Learning outcome	<u>Knowledge</u> The students will get a general overview over the mechanical properties of cells and their origin. <u>Skills</u> In particular, the course will enable the students to - predict the physical properties of polymers under given conditions and apply this knowledge to the most common biological polymers in cells. - use elasticity theory in two and three dimensions, predict properties of networks with different number of coordination and symmetries, e.g. in membrane-associated

	networks. - estimate the forces between surfaces of living organisms, e.g. in adhesion processes. - understand the origin of simple motion of living organisms and design principles for e.g. achieving an optimum size. - have basic knowledge on experimental techniques for studying physical properties of living matter, in particular cell-material interactions. <u>Competences</u> A very important aspect of this highly interdisciplinary course is that the students will learn to understand the different language of biology and in this way increase their competence to carry out interdisciplinary research in general. By working with recent research articles, the students will learn to work with literature and get knowledge about the status of international research.
Content	The course focuses on the mechanical properties of living cells. Particular emphasis will be given to the interaction of cells and materials. Content of the lectures: 1. Introduction to cell organization and structure 2. Mechanical properties of polymers 3. 2D and 3D polymer networks 4. Intermembrane forces 5. Dynamic filaments 6. Molecular motors 7. Mechanical design of cells 8. Cell adhesion 9. Imaging the cell-material contact 10. Force measurements on cells 11. Cell-material interactions In the exercises, current experimental and theoretical topics in cell mechanics will be discussed.
Assessment of course achievements	During the examination period following the module, a written exam (duration: 120 min.) on “Cell Mechanics” is held.
Media	Powerpoint presentation, blackboard, overheads, hands-on examples.
Literature	David Boal: Mechanics of the Cell, Cambridge University Press, 2001. Additional literature (scientific articles, notes) will be handed out during the course.

Module number	**Mawi 915**
Module title	**Polymer based Smart and Multifunctional Devices**
Module level	Deepening Materials Science
Abbreviation	PSMD
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. M. Elbahri
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course “Materials Science and Engineering“
Teaching methods/SWS	2 SWS lecture 1 SWS practical exercises
Work load	30 h lecture 15 h practical exercises 45 h self-organized studies 30 h revision
Credits	4
Prerequisites according to examination order	none
Recommended Prerequisites	Basics in Polymers
Learning outcome	
Content	**1.Introduction** 1.1 Emergence of the fields 1.2 State of the Art and Challenges **2. Basics and Definition** 2.1 Polymers 2.2 Stimuli - Responsive Materials 2.3 Smart and Multifunctional Materials **3. Smart Polymer in Solution and on Surface** 3.1 Basic

	3.2 Synthesis 3.3 Types *Solvent Responsive Polymers* *Temperature Responsive Polymers* *Ionically Responsive Polymers* *Electrically Responsive Polymers* *Photo Responsive Polymers* *Biochromism* 3.4 Ordering and Patterning *Self –Assembly and Self-Organization* *Phase Separation* *Bioinspired* 3.5 Polymer based Smart and Multifunctional Materials **4. Devices** Light Automobile and aerospace applications Coating Textile Catalyst Energy Electronic Medicine and Life science
Assessment of course achievements	Presentation given by the students. Content and presentation technique will be discussed. During the examination period following the module an oral exam (duration: 20-30 min.) is held.
Media	Powerpoint Blackboard
Literature	Recent Progress from reviews and papers

Module number	**Mawi 918**
Module title	**Advanced Metallic Materials**
Module level	Deepening Materials Science
Abbreviation	AMM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 4
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. F. Faupel
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 4 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	2 SWS practical exercises
Work load	30 h practical exercises 16 h preparation of presentation
Credits	3
Prerequisites according to examination order	none
Recommended Prerequisites	Basics in Metals
Content	Each participant gives a talk on a topic in the field of advanced metallic materials. The topics range from processing through structural and functional properties to applications. The talks are followed by a discussion.
Assessment of course achievements	The grade is given based on the technical quality of the presentation, the content, the response to questions, and the participation in the discussions.
Media	Laptop and beamer, blackboard
Literature	It is part of the task to find appropriate literature. On request, the lecturer gives hints also with respect to the outline of the presentation.

Module number	**Mawi 919**
Module title	**Advanced Organic Materials**
Module level	Deepening Materials Science
Abbreviation	AOM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. F. Faupel
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course “Materials Science and Engineering“
Teaching methods/SWS	2 SWS practical exercises
Work load	30 h practical exercises 16 h preparation of presentation
Credits	3
Prerequisites according to examination order	none
Recommended Prerequisites	Basics in Polymers
Content	Each participant gives a talk on a topic in the field of advanced organic materials. The topics range from processing through structural and functional properties to applications. The talks are followed by a discussion.
Assessment of course achievements	The grade is given based on the technical quality of the presentation, the content, the response to questions, and the participation in the discussions.
Media	Laptop and beamer, blackboard
Literature	It is part of the task to find appropriate literature. On request, the lecturer gives hints also with respect to the outline of the presentation.

Module number	**Mawi 921**
Module title	**Magnetic Materials: Physics and Applications**
Module level	Deepening Materials Science
Abbreviation	MagMat
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. J. McCord
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	2 SWS lecture 1 SWS practical exercise
Work load	30 h lecture 15 h practical exercise 60 h self-organized studies 45 h revision
Credits	5
Prerequisites according to examination order	none
Recommended Prerequisites	Basic lecture materials science
Learning outcome	Knowledge The aim of the module is to make the students familiar with the concepts of magnetism and the foundations of magnetic materials. An emphasis will be placed on magnetic properties that are important for applications. Skills The students will learn how to apply their knowledge of materials science and solid state physics, in order to understand the function of magnetic materials. Competences

	The students will be able to understand the current trends in magnetic materials development and will obtain the knowledge to deal with magnetic materials in research, development, as well as production.
Content	1. Fundamentals of magnetism 2. Manifestations of magnetism 3. Magnetic anisotropies 4. Magnetization processes 5. Magnetic domains 6. Soft magnetic materials 7. Hard magnetic materials 8. Spin electronics and magnetic recording
Assessment of course achievements	An oral exam (duration: 30 min.) on “Magnetic Materials” has to be passed.
Media	Powerpoint presentation Lecture notes Blackboard
Literature	Robert C. O'Handley - Modern Magnetic Materials: Principles and Applications B. D. Cullity , C. D. Graham - Introduction to Magnetic Materials J. M. D. Coey - Magnetism and Magnetic Materials

Module number	**Mawi 924**
Module title	**Bioinspired Materials**
Module level	Introduction into bio-inspired materials
Abbreviation	BIM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 4
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. C. Selhuber-Unkel
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 4 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	2 SWS practical exercises
Work load	30 h practical exercises 45 h self-organized studies 15 h revision
Credits	3 ECTS
Prerequisites according to examination order	none
Recommended Prerequisites	Advanced Materials A
Learning outcome	The students will gain knowledge on: - biological systems that currently serve as basis for bio-inspiration - already achieved success in developing materials based on biological systems - Techniques needed for biomimetics research The students will gain the following skills: - Extracting novel information about bio-inspired systems from current literature - Designing materials according to bio-inspired systems The students will learn competences regarding: - interdisciplinary work and language

	- extracting information from interdisciplinary papers - designing interdisciplinary projects
Content	The lecture will introduce into bio-inspired systems that control: - adhesion - friction - mobility - sensing - mechanics In particular, a focus will be on bio-inspiration from: - plants - animals (vertebrates, invertebrates) - human tissue The students will discuss techniques to investigate biological systems and also learn about how to put the knowledge from biology into materials.
Assessment of course achievements	An oral presentation has to be given. A written examination (duration: 120 min.) has to be passed. The final grade is the mean value of both results.
Media	Blackboard Computer projector
Literature	Scientific articles handed out during the seminar

Module number	**Mawi 929**
Module title	**Chemistry and Physics of Biomaterials**
Module level	Deepening Materials Science
Abbreviation	CPBM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. R. Willumeit-Römer
Lecturer	Professors and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	3 SWS lecture 1 SWS practical exercise (blocked in the end of the term) 1 SWS seminar (blocked in the end of the term)
Work load	45 h lecture 15 h practical exercise 15 h seminar 60 h self-organized studies 45 h revision
Credits	6
Prerequisites according to examination order	None
Recommended Prerequisites	Advanced Materials A Seminar Biochemistry
Assessment of course achievements	The students will get a general overview over biomaterials and fundamental aspects of biochemistry. In particular, the course will enable the students to - judge biomaterial properties with respect to their medical application - use theory to understand mechanical / chemical properties of biomaterials - estimate the value of biomaterials in biosensor applications - understand the forces acting on biomaterials

	- have basic knowledge on experimental techniques to study biomaterials By working with recent research articles in the seminar and studying practical experimental questions in the exercises, the students will learn to work with literature and get knowledge about the status of international research.
Content	The course focuses on the physics and chemistry of biomaterials. Content of the lectures: 1. Wetting properties 2. Implants 3. Drug delivery 4. Biosensor 5. Polymeric biomaterials 6. Dynamic biomaterials 7. Biophysical properties of biomaterials 8. Bonding of metal ions in complexes and enzymes 9. General aspects of the biochemistry of essential elements 10. Electrolytes 11. Porphyrine complexes 12. Fixation of nitrogen In the exercises and seminars, current experimental and theoretical topics in biomaterials research will be discussed.
Assessment of course achievements	A written examination (duration: 120 min.) has to be passed. Successful participation on the exercises are prerequisite for the examination.
Media	Powerpoint presentation, blackboard, hands-on examples.
Literature	• R. N. Wenzel, Ind. Eng. Chem. 28, 988 (1936). • B. D. Cassie, S. Baxter, Trans. Faraday Soc. 40, 546 (1944). • D. Quere, A. Lafuma, J. Bico, Nanotechnology 14, 1109 (2003). • DF Williams, Definitions in Biomaterials. Proc. of a Consensus Conference of the European Society for Biomaterials 1987. • DS Feldman PJ Czuwala, SS Kelpke,AS Pandit and DJ Wilson in Encyclopedic handbook of biomaterials and biomaterials 1995. • Biocompatibility of Stent Materials, MURJ: The MIT Undergraduate Research Journal, Vol. 11; Fall 2004. • SARAJU P. MOHANTY AND ELIAS KOUGIANOS, Biosensors, A tutorial review, 0278-6648/06 IEEE 2006.

	• W. Kaim, B. Schwederski: Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, Wiley 1994 • Additional material (scientific articles, book chapters) will be handed out during the course.

Module number	**Mawi 930**
Module title	**Nanomedicine**
Module level	Deepening Materials Science
Abbreviation	NaMed
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. C. Selhuber-Unkel
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	2 SWS practical exercises
Work load	30 h practical exercises 15 h self-organized studies
Credits	3
Prerequisites according to examination order	None
Recommended Prerequisites	Knowledge about magnetism, and cell biology are helpful
Assessment of course achievements	The students will gain knowledge about: - Biomedical application of nanoparticles - Techniques needed for biomedical research - State of the art in development and application of magnetic nanomaterials and sensors in medicine - Requirements for the design of biocompatible materials according to biomedical requirements The students will acquire competences regarding: - interdisciplinary work and language - extracting information from interdisciplinary papers - designing interdisciplinary projects
Content	This module will convey an overview of the highly interdisciplinary field of nanomedicine and the biomedical application of novel multifunctional nanomaterials. A special

	focus will lie on magnetic particles and biosensors. Basic principles and applications will be introduced. Representative nanoparticles and sensors will be discussed in more detail with regrads to their overall properties, distinctive features and specific biomedical use.
Assessment of course achievements	An oral examination in the end of the module has to be passed.
Media	PowerPoint Presentations
Literature	Nanomedicine: Design and Applications of Magnetic Nanomaterials, Nanosensors and Nanosystems Vijay K. Varadan, Dr LinFeng Chen, Jining Xie ISBN: 978-0-470-03351-7 Further literature will be suggested during the course.

Module number	**Mawi 932**
Module title	**Selected Topics in Solid State Chemistry**
Module level	Deepening Materials Science
Abbreviation	STSSC
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 4
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. L. Kienle
Lecturer	Professor and staff
Language	English
Assignment to the curriculum	Elective subject in term 4 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	1 SWS practical exercises
Work load	15 h practical exercises 60 h literature work 15 h preparation of presentation
Credits	*3 LP*
Prerequisites according to examination order	None
Recommended Prerequisites	General knowledge of chemistry basics, particularly solid state chemistry Solid State Physics Crystallography and structural chemistry (e.g. as treated in the lecture Material Science 3)
Learning outcome	The module should enable the students to work independent on a selected topic of solid state chemistry. Moreover, the students learn to give an optimized scientific presentation
Content	Up to five topics (for five students) will be announced! • Interested students must attend a preparatory meeting (compulsory attendance) • Each student can select a topic offered by the research group "Synthesis and Real Structure"

	• Each student must perform literature search of relevant source articles independently (ISI-web or similar scientific search engines, no plain web pages). The literature list must be discussed with Prof. Kienle and/or staff • Each student must write successfully a summary paper of 10 pages (template will be provided) • The final oral exam consists of a powerpoint presentation (30 min) and discussion (30 min.) • All students must attend all presentations
Assessment of course achievements	Presentations (30 min) given by the students. Content and presentation technique will be discussed (30 min) The presentations will be scored.
Media	Word, powerpoint
Literature	**need to be searched by the candidate**

Module number	**Mawi 933**
Module title	**Optoelectronics and Photonics**
Module level	Deepening Materials Science
Abbreviation	OEM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 4
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. J. McCord
Lecturer	Professors and staff
Language	English
Assignment to the curriculum	Elective subject in term 4 of the masters course “Materials Science and Engineering“
Teaching methods/SWS	2 SWS practical exercises
Work load	30 h practical exercises 45 h preparation 15 h revision
Credits	*3 ECTS*
Prerequisites according to examination order	none
Recommended Prerequisites	Advanced Materials B Solid State Physics Semiconductors
Learning outcome	Knowledge The aim of the module is to give the students an insight in materials for optical and photonic applications. Skills The students will learn how to apply their knowledge of materials to a field of materials science not explicitly treated in the lectures. The students will learn how to lecture a subject to an audience. Competences The students will be able to understand the fundamentals of optical materials and by this will obtain the knowledge to deal with optical materials in research and development.

Content	Contents to be reviewed and prepared by the students. • Wave nature of light • Dielectric waveguides and optical fibers • Semiconductor science and Light-Emitting Diodes • Stimulated emission devices: Optical amplifiers and lasers • Photodetectors and image sensors • Polarization and modulation of light
Assessment of course achievements	Presentations (lectures) given by the students. Content and presentation technique will be discussed. The presentations will be scored.
Media	Powerpoint presentation Blackboard or Whiteboard
Literature	S.O. Kasap, Optoelectronics & Photonics: Principles & Practices (Pearson, 2013)

Module number	**mawi 934**
Module title	**Advanced Topics in Organic Materials**
Module level	Deepening Materials Science
Abbreviation	ATOM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 4
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. F. Faupel
Lecturer	Prof. Dr. F. Faupel
Language	English
Assignment to the curriculum	Elective subject in the 4th semester of the masters course “Materials Science and Engineering“
Teaching methods/SWS	2 SWS lecture
Work load	30 h lecture 30 h literature work 30 h preparation for exam
Credits	3
Prerequisites according to examination order	None
Recommended prerequisites	Advanced knowledge on polymers and materials science, basic knowledge on solid state physics and organic chemistry
Learning outcome	Knowledge on advanced structural and particularly functional properties and applications of polymers and other organic materials including aspects of modern nanotechnology and surface science. The main skills acquired are a deeper understanding of the relationship between structure and properties of organic materials on all length scales and how this understanding can be used to develop novel materials.

	Competence to understand scientific literature and patents on organic materials and to apply this to successfully work in research and development.
Content	Depending on time, interests of the students, and the latest developments in the field, the following topics will be covered: • Reinforcement of polymers on all length scales • Functional polymer nanocomposites • Liquid crystalline polymers • Conducting and semiconducting polymers • Polymers in microelectronics • Polymer electrolytes • Ferroelectric polymers • Polymer electrets • Organic thin films • Polymer surfaces • Shape-memory polymers • Electroactive polymers • Polymer gels • Adhesives
Assessment of course achievements	Written exam at the end of the semester
Media	PowerPoint, blackboard
Literature	Since the lecture aims at including the latest developments in the field, the updated literature will be given in the lecture and in the lecture notes which are available on the website of the Chair for Multicomponent Materials.

Module number	**mawi 935**
Module title	**Advanced Topics in Metallic Materials**
Module level	Deepening Materials Science
Abbreviation	ATMM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 4
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. K. Rätzke
Lecturer	Prof. Dr. K. Rätzke
Language	English
Assignment to the curriculum	Elective subject in term 4 or term 2 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	2 SWS practical exercises
Work load	30 h practical exercises 30 h literature work 30 h preparation for exam
Credits	3
Prerequisites according to examination order	None
Recommended prerequisites	General knowledge of chemistry, basics solid state physics, crystallography and structural chemistry lecture advanced materials A, / Metals
Learning outcome	Knowledge in depth understanding of structure and properties of metals understanding alloy design Skills and Competences prediction of properties from alloy content and thermal history know and apply latest metallic alloys

Content	Ferrous alloys (Steel, cast iron) Non ferrous engineering alloys (Al, Cu, Mg, etc.) Special alloys (Metallic glasses, Quasicrystals, Intermetallics, Metallic foams, High entropy alloys) Special properties (superplasticity, electromigration, etc.)
Assessment of course achievements	Written exam at the end of the semester
Media	Powerpoint, blackboard
Literature	• Askeland, *Science and Engineering of Materials* • Shackelford, *Introduction into Materials Science for Engineers* • Haasen, *Physical Metallugry*

Module number	**mawi 936**
Module title	**Finite-Element Modelling in the Mechanics of Materials**
Module level	Deepening Materials Science
Abbreviation	FEM
Subtitle (if applicable)	
Courses (if applicable)	
Study term	Term 3
Responsible Institute	Institute for Materials Science
Responsible staff member	Dr. D.Steglich
Lecturer	Dr. D. Steglich and stuff
Language	English
Assignment to the curriculum	Elective subject in term 3 of the masters course "Materials Science and Engineering"
Teaching methods/SWS	3 SWS lecture and computer exercises
Work load	45 h lecture 60 h computer exercises 45 h revision
Credits	5
Prerequisites according to examination order	None
Recommended prerequisites	vector und tensor analysis, structural mechanics, knowledge of windows operating systems
Learning outcome	Modelling in theory and praxis, realization of stability analysis by the model of finite elements Creation and optimisation of models, error free simulation, interpretation and critical review Abstracting from 3D into 2D, understanding and assessing of mechanical treatment, communication with structure mechanics

Content	Models in engineering and science are addressed in general. The terminology used to formulate field problems will introduced. Modelling errors and their respective treatment based on model verification and validation are explained. The general structure of a FE program will be treated: necessary input data, flow of solution steps, post-processing of resulting data. The hybrid method of mechanical testing and FE simulation for parameter identification is illustrated and trained. The course will be accompanied with practical exercises using the commercial FE-code ABAQUS.
Assessment of course achievements	Four homeworks to hand in two weeks after issued Written exam at the end of the semester
Media	Powerpoint, blackboard
Literature	• K. Knothe: Finite Elemente - Einführung für Ingenieure, Springer 1992 • J. N. Reddy: An introduction to the finite element method, McGrw-Hill, 2006 • C. A. Felippa: Introduction to Finite Elements Methods, http://www.colorado.edu/engineering/cas/courses.d/IFEM.d/ • A. F. Bower, Applied Mechanics of Solids, http://solidmechanics.org/

Interdisciplinary Non Technical Elective Modules

Module number	**Mawi E-002**
Module title	**Nano Ethics Technology 1**
Module level	Interdisciplinary Content
Abbreviation	NET1
Subtitle (if applicable)	
Courses (if applicable)	
Study term	
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. R. Adelung
Lecturer	Professor and staff
Language	German / English
Assignment to the curriculum	Interdisciplinary subject for all studies
Teaching methods/SWS	2 SWS seminar
Work load	30 h seminar 30 h self-organized studies 30 h seminar (revision)
Credits	3
Prerequisites according to examination order	-
Recommended Prerequisites	-
Content	
Assessment of course achievements	
Media	
Literature	

Module number	**Mawi E-003**
Module title	**Nano Ethics Technology 2**
Module level	Interdisciplinary Content
Abbreviation	NET2
Subtitle (if applicable)	
Courses (if applicable)	
Study term	
Responsible Institute	Institute for Materials Science
Responsible staff member	Prof. Dr. R. Adelung
Lecturer	Professor and staff
Language	German / English
Assignment to the curriculum	Interdisciplinary subject for all studies
Teaching methods/SWS	2 SWS seminar
Work load	30 h seminar 30 h self-organized studies 30 h seminar (revision)
Credits	3
Prerequisites according to examination order	-
Recommended Prerequisites	-
Content	
Assessment of course achievements	
Media	
Literature	

Imported
Technical Elective Modules
of the Master Course

The following modules from other institutes are registered as technical electives for the Master Course Materials Science and Engineering:

Institute of Biology

Module Code	**Title**
biol 167	Basics of Biomimetics
biol 281	Methods of the Biomechanics and Biomimetics
biol 252	Biomechanics and Biomimetics with the Emphasis on Surfaces
biol 281	Methods of the Biomechanics and Biomimetics