MODULE HANDBOOK FOR THE MASTER'S PROGRAMME

Materials Science

Effective October 1, 2025

MONTAN UNIVERSITÄT LEOBEN

UNILEOBEN.AC.AT

General information

A central component of the Bologna Process is the modularisation of academic programmes, i.e. the implementation of a module system in which the courses are bundled into thematically related course blocks - i.e. modules.

This module handbook contains the descriptions of all modules offered as part of the Master's programme in Materials Science. The purpose of the module handbook is to increase transparency and to provide registered and prospective students with specific details pertaining to the individual modules, in particular their learning objectives as well as qualitative and quantitative requirements.

Terminology:

Modules comprise teaching and learning content that is merged into units of a study programme according to didactic and thematic criteria. Didactically or thematically related modules can be combined into module blocks with a maximum of 30 ECTS credits.

- **Core modules** are modules that are mandatory to complete in order to achieve the qualification profile of a study programme.
- **Profile modules** are modules that can be elected according to the specifications of the curriculum.

A module should be completed in the designated semester. The achievement of the learning outcomes is monitored following the principles of competence-oriented assessment.

- **Single Examination Module (MN)**

  Examination involves a single examination process. At least three examination dates per semester must be announced prior to the beginning of the semester.

  Continuous formative assessment is recommended (voluntary, does not count as an exam, but e.g. possibility for bonus points)

- **Continuous Evaluation Module (MI)**

  Continuous assessment of the achievement of learning outcomes during the semester, e.g. through tests, project work, reports, presentations, reflections, compulsory attendance (up to max. 80%)

  If provided for in the curriculum, an MI module can also be completed as an MN module. In this case, the student must announce his/her intention to opt for the “unsupervised” track before registering for the module. This option expires if a module has to be repeated.

Further information can be found in Satzungsteil für Studienrechtliche Bestimmungen (in German only).

Markings used:

Underlined captions: The requested information is also is also to be found in - and must be consistent with - the corresponding curriculum.

Captions with an asterisk*: The requested information is also to be entered in - and must be consistent with - MUonline.

Period of validity:

Prior to the beginning of the new academic year, the module handbook will be updated and published.

MODULE DIRECTORY

Core Module
Metallic Materials I

Module block: Metallic Materials

Module Details		Module Number*	420.265
Organization*	Chair of Physical Metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Ronald SCHNITZER		
Deputy Head of Module	Dipl.-Ing. Dr.mont. Oliver RENK		
Contributor*	Ao.Univ.-Prof. Dipl.-Ing. Dr.mont. Christian BERNHARD, Ass.Prof. Dipl.-Ing. Dipl.-Ing. Dr.mont. Sabine BODNER		
Abstract	This module covers the fundamentals of steel production and processing, secondary metallurgy and the production of high-alloyed steels. In terms of physical metallurgy, the content covers high-temperature materials such as Co- and Ni-based superalloys and the creep of metals and their mechanisms are taught.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒	WS	☐	SS
Module type*	☐	**MI** (cont. evaluation)	☒	**MN** (single examination)
Contact hours*	4			
ECTS credits*	5			
Participation quota*	☒	no	☐	yes

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	0%

Module Details	**Module Number***	**420.265**

Module Description

The module consists of two parts. The first one covers the fundamentals of steel production and processing, secondary metallurgy and the production of high-alloyed steels. The second one deals with the physical metallurgy of high-temperature materials such as Co- and Ni-based superalloys and the creep of metals and their mechanisms are taught

Moodle support*

☒ yes ☐ no

Course Work / Evaluation

Learning outcomes*

Upon successful completion of the module, students will be able to:

(i) Evaluate technical and economic challenges in the production of green steel,

(ii) Create processing -structure and property relationships of metallic alloys,

(iii) Develop new metallic high temperature and lightweight materials,

(iv) Apply advanced knowledge of creep behavior of materials.

Contents*

The course will cover

(i) production and processing of steels

(ii) Ni-based superalloys

(iii) Co-based superalloys

(iii) creep of materials

(iv) Ti-alloys

(v) Al-alloys

(vi) refractory metals

Module Details	Module Number*	420.265

Evaluation - Examination*

The assessment takes the form of a 180-minute written exam. The examination is divided into the two above mentioned parts, each taking 90 minutes. In sum a minimum of 50% of the maximum achievable points is necessary to pass the exam.

Grading scheme*

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Mathematics, physics, chemistry, technical mechanics, thermodynamics, technology of metallic materials, construction of phase diagrams from G-x curves, iron-carbon phase diagram, application of heat treatments, assessment of precipitation processes and phase developments, metallographic investigations and interpretation of micrographs.

Remarks*

n/a

Core Module
Ceramic Materials I

Module block: Ceramic Materials

Module Details		Module Number*	410.005
Organization*	Chair of Structural and Functional Ceramics		
Organization ID	410		
Module Manager	Univ.-Prof. Dr. Raul BERMEJO		
Deputy Head of Module	Ao.Univ.-Prof. Dr.mont. Peter SUPANCIC		
Contributor*	Univ.-Prof. Dr. Raul BERMEJO, Ao.Univ.-Prof. Dr.mont. Peter SUPANCIC, Dr. Abdullah JABR, DI. Irina KRALEVA, Dr. Josef KREITH		
Abstract	This module addresses the significance of crystal structure, types of defects, and microstructures, as well as the relationships between density, grain size, and sintering conditions in relation to the thermal, optical, and electrical properties of ceramic materials for engineering applications.		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☒ WS	☐ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	5		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	40%

Module Details	**Module Number***	**410.005**

Module Description

The module consists of three parts:

Part 1 gives an overview on the importance of the crystal structure, type of defects and microstructures on the final properties of inorganic materials.

Part 2 focusses on the processing and fabrication of ceramics using several forming techniques, such as Tape Casting or 3D-printing.

Part 3 explores the sintering of ceramics using conventional and non-conventional techniques.

Part 4 deals with the thermal, optical and electrical properties of ceramics and their relation to crystal structure and microstructure.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the lecture, students have acquired the following knowledge and skills and are able to take over project management, decisions and responsibilities:

- Critical judge and assess the importance of the crystal structure, type of defects and microstructures on the final properties of inorganic materials for technical applications.
- Design and formulate processing steps (from slurry preparation to shaping of the final part) for the fabrication of structural and functional ceramics
- Categorize sintering mechanisms in ceramics and interpret ceramic microstructures through an understanding of the physics and chemistry of densification and grain growth, justifying correlations btw. density, grain size and sintering conditions.
- Assess the correlation between crystal structure, microstructure and functional properties (thermal, optical and electrical) in ceramics and glasses.
- Devise the design of ceramic components with enhanced functional performance based on material's selection, shaping technique and sintering protocols.

Module Details	Module Number*	410.005

Contents*

The course will cover:

+ Introduction to ceramics science and engineering

(i) Atomic bonding and crystal structures in ceramics and glasses (considering simple and complex structures)

(ii) Defects in ceramic structures: point defects, solid solutions (important phase diagrams)

+ Processing of ceramics (slip casting, tape casting, 3D-printing): from slurry preparation to shaping

Lab#1: categorize important parameters in the shaping of a ceramic part using Tape Casting and/or 3D-printing

+ Sintering process explained based on solid state physics: microstructure formation (densification, grain growth)

+ Non-conventional sintering: tailoring microstructure and properties (cold sintering, spark plasma sintering)

Lab#2: interpret and argue the different grain size obtained with different sintering methods

+ Thermal properties: thermal expansion, conductivity, diffusivity (comparison ceramics and glasses)

+ Optical properties: translucency, transparency, importance of microstructure

+ Electrical properties: electrical conductivity, dielectrical properties (polarisation), piezoelectricity

Lab#3: measure dielectric constant in a electroceramic (e.g. $BaTiO_3$) with different grain sizes

Evaluation - Examination*

Evaluation is based on continuous tests (KNM) after the different units and lab courses protocols.

For the assessment of the content in Part 1, a 60-min exam (written and/or oral) will take place, where the students should demonstrate that they have obtained the required skills and competences in defects in ceramics and implications in the microstructural properties.

Part 2 will be examined based on the protocol and test (approx. 20 min) after the exercises in the processing lab. A mandatory attendance of 20 % is needed.

For the assessment of the content in Part 3, a 60-min exam (written and/or oral) will take place, where the students should demonstrate that they have obtained the required skills and competences in sintering of ceramics.

Part 4 will be examined based on the protocol and test (approx. 20 min) after the exercises in the electroceramic lab. A mandatory attendance of 20 % is needed.

The grades reached in all four parts contribute with equal shares to the overall grade of the module.

Module Details	Module Number*	410.005

Grading scheme*

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The theoretical foundations are taught in classical lecture style using a projector and a chalkboard supported by Moodle.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

In will be given in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Key knowledge, skills and responsibilities for bachelor engineers (mathematics, physics, chemistry, technical mechanics, fundamentals of structural and functional materials, crystallography, ceramics technology.

Remarks*

n/a

Core Module
Functional Materials I

Module block: Functional Materials

Module Details		Module Number*	425.205
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER		
Deputy Head of Module	Priv.-Doz. Dr. Dipl.inz.elektr. Aleksandar MATKOVIC		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER, Priv.-Doz. Dr. Dipl.inz.elektr. Aleksandar MATKOVIC, Priv.-Doz. Dipl.-Ing. Dr.mont. Nina SCHALK		
Abstract	This module is dedicated to the development of the materials science fundamentals of functional materials as well as selected examples of functional materials. The focus is laid on scientific correlations between material structure and the associated material properties and the application behavior.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒ WS	☐ SS		
Module type*	☐ **MI** (cont. evaluation)	☒ **MN** (single examination)		
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒ no	☐ yes		

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	0 %

Module Details	Module Number*	425.205

Module Description

The module consists of three parts.

In part 1, materials science fundamentals needed for a solid understanding of phenomena and mechanisms used in functional materials will be explained and discussed.

In part 2, an overview on selected functional materials, including their manufacturing, structure, properties and used functional mechanism will be given.

In part 3, an excursion to functional materials laboratories at Montanuniversität Leoben will be offered.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the lecture, students have acquired the following knowledge, skills and competences:

- Highly specialized knowledge, some of which is at the forefront of knowledge in the field of functional materials, to establish the materials science basis for original thinking and ideas for research.
- Critical awareness of knowledge issues in the field of functional materials, including future potentials and present limits of applicability.
- Specialized problem-solving skills required in research in the field of functional materials, to establish the basis for gaining new research findings and future materials innovations.
- Responsibility to conceptionally design and perform complex, unpredictable research and development tasks necessitating novel strategic approaches.

Module Details	Module Number*	425.205

Contents*

Within this module, the fundamental key knowledge, skills and competences necessary for research and application of functional materials will be communicated and trained. The module covers the following topics:

- Fundamentals of functional materials
  - Crystal lattices
  - Phase transformations (thermodynamics and kinetics)
  - Semiconductor physics (electron transport, band structure, optical properties)
  - Magnetism (magnetic moment, ferromagnetism, domains and Bloch walls, hysteresis)
  - Thermoelectricity (electron and phonon transport)
  - Tribology (friction, wear and lubrication)
- Structure, functionality and application of selected functional materials
  - Shape memory alloys (responsible mechanisms and materials for conventional and ferromagnetic shape memory alloys)
  - Energetic materials used for cooling and heating
  - Self-healing materials (mechanisms applied to concrete, ceramics, metals)
  - Magnetic materials (fundamentals of magnetism, soft and hard magnets)
  - Chromogenic effects and materials (electro- and thermochromic effects)
  - Thermoelectric materials (Seebeck, Peltier and Thomson effect)
  - Biocompatible materials
  - Self-lubricating materials
  - Materials for energy harvesting, conversion and storage
  - Semiconductor materials
  - Transparent conductive oxides
  - 2D materials
  - Electrical contact materials
- Lab excursions
  - Plasma-assisted thin film deposition
  - Physical vapor transport

Evaluation - Examination*

The assessment takes the form of a 120-minute written exam, where the students should demonstrate that they have obtained the required skills and competences in functional materials. A minimum of 50% of the maximum achievable points is necessary to pass the exam.

Grading scheme*

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Module Details	Module Number*	425.205

Teaching and learning methods*

The teaching format is a frontal lecture supported by Moodle and enriched by excursions to functional materials laboratories at Montanuniversität Leoben.

Learning material and required equipment

Lecture notes are provided via Moodle.

Literature*

N.W. Ashcroft, N.D. Mermin, Solid State Physics, Saunders College Publishing, Forth Worth, 1976

D.C. Lagoudas (ed.), Shape Memory Alloys, Springer, Berlin, 2008

S. van der Zwaag, Self Healing Materials, Netherlands Enterprise Agency, The Hague, 2014

L. Michalowsky, J. Schneider, Magnettechnik, Vulkan, Essen, 2006

R.P. Feynman, R.B. Leighton, M. Sands, Lectures on Physics, Addison-Wesley, Reading Massachusetts, 1965 (in particular Vol. 1 - chapters 1, 28, 37; Vol. 2 – chapters 1, 4, 13, 34, 35-37; Vol. 3 – chapters 13-17)

K. Seeger, Semiconductor Physics: An Introduction, Springer Berlin Heidelberg, 1991

W. Shockley, Electrons and Holes in Semiconductors - with Applications to Transistor Electronics, D. Van Nostrand Company, Princeton, New Jersey, 1966

M. Schwartz (ed.), Smart Materials, CRC Press, Boca Raton, 2009

Th. Klooster, Smart Surfaces, Birkhäuser, Basel, 2009

M.O. Speidel, Materials in Medicine, vdf, Zürich, 1998

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Fundamental key knowledge, skills and competences for engineers (mathematics, physics, chemistry, technical mechanics); knowledge, skills and competences in digital sciences and statistics; materials science of metals, ceramics, semiconductors and polymers; fundamentals of materials technology; materials characterization and testing with a level corresponding to a Bachelor degree.

Remarks*

n/a

Core Module
Materials Technology I

Module block: Materials Technology

Module Details		Module Number*	420.269
Organization*	Chair of Physical Metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Ronald SCHNITZER		
Deputy Head of Module	Univ.-Prof. Dipl.-Ing. Dr.mont. Martin STOCKINGER		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Peter HOFER-HAUSER		
Abstract	This module is dedicated to the basics of casting, casting materials and casting processes. Furthermore, the basics of forming technology as well as the deformation and flow behavior of materials are taught.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒ WS		☒ SS	
Module type*	☒ **MI** (cont. evaluation)		☐ **MN** (single examination)	
Contact hours*	4			
ECTS credits*	5			
Participation quota*	☒ no		☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	40%

Module Details	**Module Number***	**420.269**

Module Description

The module consists of a theoretical part, which is taught as a frontal lecture with attendance not mandated but recommended, as well as a practical part done mostly in labs, where a minimum attendance of 80% is mandatory.

The content of the module consists of two fields. The first one covers the basics of casting, casting materials and casting processes The second one deals with the basics of forming technology as well as the deformation and flow behavior of materials. Both fields comprises theoretical and a practical parts, respectively.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

Upon successful completion of the module, students will be able to:

(i) evaluate the influence of casting processes on the casting structure and component properties,

(ii) apply advanced knowledge of the technological fundamentals of casting technology,

(iii) explain the metal-physical and plastomechanical fundamentals of the formability of metallic materials,

(iv) use the process-related influences on the forming behavior in the form of mechanism and stability maps according to Prasad for the design of forming processes,

(v) explain the influence of forming processes on microstructure development and mechanical properties,

(vi) carry out the component and material-dependent selection of suitable forming processes.

Contents*

The course will cover

(i) Casting Technology

(ii) Metal forming

Module Details	Module Number*	420.269

Evaluation - Examination*

Casting Technology:

Part 1: Successful completion of the module requires a minimum attendance of the lab exercises, as well as a positive assessment on continuous tests after the different units and lab courses protocols.

Part 2: The theoretical part, where attendance is not mandatory, will be assessed by a 90-minute written exam.

Metal forming:

Part 3: Successful completion of the module requires a minimum attendance of the lab exercises, as well as a positive assessment on continuous tests after the different units and lab courses protocols.

Part 4: The theoretical part, where attendance is not mandatory, will be assessed by a 90-minute written exam.

For Part 1 and Part 3 together a minimum attendance of the lab exercises of 80% of all tutorial units is necassay.

Both content fields (*Casting technology* and *Metal forming*) have to achieve a minimum of 50% of the maximum achievable points.

Grading scheme*

After fulfilling the requirement of minimum attendance and after positive completion of both content fields, the achieved total percentage is calculated as a weighted average of the percentages of Part 1-4, respectively.

P = 0.2*Part 1 + 0.3*Part 2 + 0.2*Part 3 + 0.3*Part 4

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0%:	Very good (1)
75.0% ≤ P < 87.5%:	Good (2)
62.5% ≤ P < 75.0%:	Satisfactory (3)
50.0% ≤ P < 62.5%:	Sufficient (4)
0.0% ≤ P < 50.0%:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard.

The exercises will be done in labs and seminar rooms. Continuous tests will be done before or after the lab units and practical experiments will be performed in group works.

Module Details	Module Number*	420.269
Learning material and required equipment		
Lecture notes are provided and will be made available on Moodle.		
Literature*		
Will be announced in the course.		
Prerequisite courses / modules for registration		
n/a		
Expected previous knowledge*		
Comprehensive knowledge and skills for Bachelor engineers (mathematics, physics, chemistry, technical mechanics, thermodynamics, metallic materials technology).		
Remarks*		
n/a		

Core Module
Mechanics of Materials

Module block: Physics and Mechanics of Materials

Module Details		**Module Number***	**430.901**
Organization*	Chair of Materials Physics		
Organization ID	430		
Module Manager	Dipl.-Ing. Dr.mont. Anton HOHENWARTER		
Deputy Head of Module	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER		
Contributor*	Dipl.-Ing. Dr.mont. Anton HOHENWARTER, Dipl.-Ing. Dr.mont. Markus ALFREIDER, Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER		
Abstract	This module deals with the deformation and fracture behaviour of metallic materials. Special attention is paid to the correlation between the existing microstructure and the resulting material behaviour on a wide range of length scales.		

General Data		
Module level	Master	
Language*	English	
Recommended semester*	☒ WS	☐ SS
Module type*	☐ **MI** (cont. evaluation)	☒ **MN** (single examination)
Contact hours*	4	
ECTS credits*	5	
Participation quota*	☒ no	☐ yes

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	0%

Module Details	Module Number*	430.901

Module Description

The module consists of three thematic blocks which are held as frontal lectures.

- Fracture mechanics of materials (40%)
- Deformation mechanics of materials (40%)
- Mechanics of confined volumes and thin films (20%)

After the presentation of the 3 thematic blocks there will be a written exam at which at least 50% of the points must be achieved for a positive module evaluation.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the module, students have acquired the following knowledge, skills and responsibilities:

(i) Interpretation of deformation and failure mechanics of modern materials in bulk form as well as thin films.

(ii) Evaluation of advanced material properties regarding the intricate interplay of microstructure, loading conditions and environmental influences on the resulting deformation, failure and fatigue mechanisms and judging future potentials and appraising current limits of their applicability.

(iii) Developing an in-depth understanding for material behaviour under cyclic loading.

(iv) Formulating and selecting strategies for a structural optimization of modern materials and material systems by microstructural design.

Contents*

Within this module material deformation and failure upon quasi-static and cyclic loading conditions will be assessed, compared with emphasis on the correlation between microstructure and material behavior from the mechanical and physical viewpoint. The course covers:

(i) The terms strength, plasticity, hardening and fracture, as well as their microscopic origins in conventional coarse grained materials will be repeated and distinguished.

(ii) Mechanistic description and analysis of deformation across the length scales of materials, from single crystal and coarse-grained microstructures over nanocrystalline states to amorphous matter, also evaluating the behavior of materials in confined volumes (e.g. thin films).

(iii) Categorizing material failure covering all important material length scales in materials.

(iv) Fracture mechanics description and discussion based on elastic and elastic-plastic fracture approaches and its assessment in engineering application for quasi-static as well as cyclic loads.

Module Details	Module Number*	430.901

Evaluation - Examination*

The assessment takes the form of a 120-minute written exam and is divided into the three above mentioned parts. In sum a minimum of 50% of the maximum achievable points is necessary to pass the exam.

Grading scheme*

The overall grade is determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

- Fracture mechanics:

T. L. Anderson: Fracture Mechanics: Fundamentals and Applications (CRC Press Inc)

- Microstructure and mechanical properties

G. Gottstein: Physical Foundations of Materials Science (Springer)

- Thin films:

L.B. Freund, S. Suresh: Thin Film Materials (Cambridge University Press)

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Demonstrate comprehensive knowledge of metallurgy, materials testing, microstructure characterization techniques, and infer the influence of crystal defects on mechanical properties. Express fundamental understanding of the theory of elasticity and plastic deformation, as well as mechanisms of plasticity. Demonstrate basic knowledge of thin film technology and thin film properties.

Remarks*

n/a

Core Module
Metallic Materials II

Module block: Metallic Materials

Module Details		Module Number*	420.266
Organization*	Chair of Physical Metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Ronald SCHNITZER		
Deputy Head of Module	Dipl.-Ing. Dr.mont. Oliver RENK		
Contributor*	Dr.mont. Bak.fk. Oleksandr GLUSHKO, Ass.Prof. Dipl.-Ing. Dipl.-Ing. Dr.mont. Sabine BODNER		
Abstract	This module deals with the alloy design, microstructure and properties of high-performance steels and non-ferrous metal alloys. In addition, methods of atomistic simulation are dealt with and experimental methods for determining recrystallization behavior and grain growth are learned.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☐ WS	☒ SS		
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)		
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒ no	☐ yes		

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	40%

Module Details	Module Number*	420.266

Module Description
The module consists of a theoretical part, which is taught as a frontal lecture with attendance not mandated but recommended, as well as a practical part done mostly in labs, where a minimum attendance of 80% is mandatory. The content covers the alloy design, microstructure and properties of high-performance steels and non-ferrous metal alloys. In addition, methods of atomistic simulation are dealt with and experimental methods for determining recrystallization behavior and grain growth are learned.
Moodle support*
☒ yes ☐ no

Course Work / Evaluation
Learning outcomes*
On successful completion of the module students will be able to: (i) Investigate structure-property relationships of metallic alloys, (ii) Develop new high performance steels, (iii) Produce phase diagrams by applying experimental characterization methods, (iv) Assess the accuracy of measurements for the study of recrystallization behaviour and grain growth, (v) Evaluate discrepancies between calculations and experiments.
Contents*
The course will cover (i) Physical metallurgy on the atomistic level (ii) non-ferrous alloys (iii) high-performance steels
Evaluation - Examination*
Part 1: Successful completion of the module requires a minimum attendance of the lab exercises of 80% of all tutorial units, as well as a positive assessment on continuous tests after the different units and lab courses protocols. Part 2: The theoretical part, where attendance is not mandatory, will be assessed by a 120-minute written exam. A minimum of 50% of the maximum achievable points is necessary to pass the exam. Both parts have to achieve a minimum of 50% of the maximum achievable points.

Module Details	Module Number*	420.266

Grading scheme*

After fulfilling the requirement of minimum attendance and after positive completion of both parts, the achieved total percentage is calculated as a weighted average of the percentages of Part 1 and Part 2, respectively.

P = 0.4*Part 1 + 0.6*Part 2

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0%:	Very good (1)
75.0% ≤ P < 87.5%:	Good (2)
62.5% ≤ P < 75.0%:	Satisfactory (3)
50.0% ≤ P < 62.5%:	Sufficient (4)
0.0% ≤ P < 50.0%:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard.

The exercises will be done in labs and seminar rooms. Continuous tests will be done before the lab units and practical experiments will be performed in group works.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Mathematics, physics, chemistry, technical mechanics, thermodynamics, technology of metallic materials, construction of phase diagrams from G-x curves, iron-carbon phase diagram, application of heat treatments, assessment of precipitation processes and phase developments, metallographic investigations and interpretation of micrographs.

Remarks*

n/a

Core Module
Ceramic Materials II

Module block: Ceramic Materials

Module Details		Module Number*	410.002
Organization*	Chair of Structural and Functional Ceramics		
Organization ID	410		
Module Manager	Univ.-Prof. Dr. Raul BERMEJO		
Deputy Head of Module	Ao.Univ.-Prof. Dipl.-Ing. Dr.mont. Tanja LUBE		
Contributor*	Univ.-Prof. Dr. Raul BERMEJO, Ao.Univ.-Prof. Dipl.-Ing. Dr.mont. Tanja LUBE, Dr. Josef SCHLACHER, Dr. Maximilian STAUDACHER, Dr. Walter HARRER.		
Abstract	This module covers the mechanical characterization of ceramic materials through strength and fracture toughness measurements, as well as the application of Weibull statistics, linear elastic fracture mechanics, and fractography. The acquired competencies are applied to the design of novel, bioinspired, and damage-tolerant inorganic materials.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☐	WS	☒	SS
Module type*	☒	**MI** (cont. evaluation)	☐	**MN** (single examination)
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒	no	☐	yes

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	40%

Module Details	Module Number*	410.002

Module Description

The module consists of four parts:

Part 1 gives an overview on brittle fracture and how to be applied to ceramic materials, including linear elastic fracture mechanics and Weibull statistics and focusses on the mechanical behaviour of ceramics under in-service conditions: bending, contact loading, thermal shock, etc. Different testing methods to measure strength and toughness and their applicability to ceramic materials, including fractographic analysis are introduced.

Part 2 consists of 2 lab exercises to investigate thermal shock behaviour and fracture toughness of ceramics.

Part 3 involves the preparation and presentation and defence of a case study on selected ceramics designed for damage tolerance.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the lecture, students have acquired the following knowledge and skills and are able to take over project management, decisions and responsibilities:

- Use the LEFM applied to brittle solids to interpret correlations between critical defects and strength in brittle solids.
- Argue and justify the mechanical behaviour of ceramic materials under different environments and loading conditions (e.g. contact or thermal shock) and differentiate it from that of polymers and metals.
- Revise, evaluate and compare measured strength and toughness data obtained with a given method.
- Design of (damage tolerant) ceramic components and glasses with enhanced performance based on material’s selection, microstructure tailoring and architectural design.

Module Details	Module Number*	410.002

Contents

The following topics are addressed ion the module:

Introduction to brittle fracture

(i) Linear elastic fracture mechanics (LEFM): Griffith criterion

(ii) Statistical theory of strength: correlation between defects and strength, size effect

(iii) Fracture toughness and toughening mechanisms in ceramics

Mechanical behaviour under in-service conditions: bending (uniaxial and biaxial), SCCG, contact loading, thermal shock, creep, proof testing and lifetime prediction (SPT-diagrams)

Lab#1: estimate and justify critical thermal shock temperature difference for two geometries

Testing methods for characterizing ceramic materials and components:

(i) Strength measurements (standard and non-conventional methods): B3B, RoR, etc.

(ii) Toughness measurements (standard and non-conventional methods): SCF, NBT, B3B-K_{Ic}, etc.

Fractography and failure analysis of advanced ceramics: practical examples on single crystals, LTCC substrates and electroceramic components. Benchmark of ceramics for structural applications

Lab#2: measure and compare the fracture toughness of a ceramic using different methods

Designing of damage tolerant ceramics and glasses

(i) Bio-inspired concepts (texture) to increase toughness

(ii) Gorilla@glass design (residual stress) to increase strength and reduce SCCG sensitivity.

Lab#3 (case study): choose a design strategy to increase damage tolerance and/or strength combining two ceramic materials of your choice. Present and judge your selection in the framework of Weibull statistics and brittle fracture for a given application.

Evaluation - Examination*

Assessment of the module is done by continuous evaluation.

Within parts 1, assessment will take place within two 60-min exams, where the students should demonstrate that they have obtained the required skills and competences on the mechanical behaviour and testing of structural ceramics under different loading situations and environments. (50% of grading)

For part 2, a mandatory attendance of 100 % is needed (Lab#1, Lab#2), in addition to submission of experimental protocols and reports regarding evaluation and comparison of toughness on selected ceramic samples (25% of grading)

Within part 3, a case study on a selected “bio-inspired” ceramic architecture needs to be prepared, presented and defended (25% of grading).

Module Details	Module Number*	410.002

Grading scheme*

After fulfilling the requirement of minimum attendance the overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0%:	Very good (1)
75.0% ≤ P < 87.5%:	Good (2)
62.5% ≤ P < 75.0%:	Satisfactory (3)
50.0% ≤ P < 62.5%:	Sufficient (4)
0.0% ≤ P < 50.0%:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundations are taught in classical lecture style using a projector and a chalkboard supported by Moodle. Part 4 involved problem-based learning, where a defined case study on a selected functional materials system needs to be prepared and presented. The completion of the case study will require reading, literature research.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Will be announced during the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Students are expected to have foundational knowledge in mathematics, physics, chemistry, engineering mechanics, structural materials, as well as materials testing and materials mechanics at the level of a bachelor's degree in materials science and/or engineering.

Remarks*

n/a

Core Module
Functional Materials II

Module block: Functional Materials

Module Details		Module Number*	425.206
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER		
Deputy Head of Module	Priv.-Doz. Dipl.-Ing. Dr.mont. Nina SCHALK		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER, Priv.-Doz. Dipl.-Ing. Dr.mont. Nina SCHALK, Ing. assoz.Prof. PhD Rostislav DANIEL, Priv.-Doz. Dipl.-Ing. Dr.-Ing. Verena MAIER-KIENER, Dipl.-Ing. Dr.mont. Anna HOFER-ROBLYEK, Dipl.-Ing. Dr.mont. Maximilian SCHIESTER		
Abstract	This module deals with selected functional materials systems, with a special focus on the methods used for their production, characterization, testing and deterioration. The competences to be acquired are consolidated and deepened through experiments in the laboratory and through examples of problem- and challenge-based learning.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☐ WS	☒ SS		
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)		
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒ no	☐ yes		

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	45%

Module Details	**Module Number***	**425.206**

Module Description

The module consists of four parts:

Part 1 gives an overview on suitable process techniques to manufacture functional materials and materials systems.

In part 2, an overview on selected functional materials systems, including their manufacturing, design and architecture, properties and application performance including degradation is given.

Part 3 is focused to demonstrations and experimental work on synthesis and characterization of functional materials and materials systems.

Part 4 involves the preparation and presentation of a case study on a selected functional materials system.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the lecture, students have acquired the following knowledge, skills and competences:

- Highly specialized knowledge, some of which is at the forefront of knowledge in the field of functional materials and materials systems, their fabrication, characterization, testing and degradation, to establish the materials science basis for original thinking and ideas for research.
- Critical awareness of knowledge issues in the field of functional materials and materials systems, their fabrication, characterization, testing and degradation, including future development trends and potentials and present limits of applicability.
- Specialized problem-solving skills required in research in the field of functional materials and materials systems, their fabrication, characterization, testing and degradation, to establish the basis for gaining new research findings and future materials innovations.
- Responsibility to conceptionally design and perform complex, unpredictable research and development tasks necessitating novel strategic approaches.

Module Details	Module Number*	425.206

Contents*

Within this module, the fundamental key knowledge, skills and competences necessary for research and application of functional materials and materials systems, including their manufacturing, characterization, testing and degradation will be communicated and trained. The module covers the following topics:

- Fabrication of functional materials and materials systems
  - Melt metallurgy (Bridgman-Stockbarger, Czochralski, Physical Vapor Transport)
  - Powder metallurgy
  - Surface modification
  - Coating and thin film deposition
  - Patterning and etching techniques
- Designing of functional materials and materials systems for
  - Tribological surfaces
  - Oxidation and corrosion protection
  - Medical implants
  - Materials for environmental technologies
  - Self-cleaning surfaces (Lotus effect, super-hydrophilicity, super-hydrophobicity, photocatalytic effect)
  - Microelectronic devices
  - Micro-electromechanical systems
  - Displays
- Lab experiments
  - Thin film deposition
  - Microstructure characterization (X-ray diffraction, Raman spectroscopy)
  - Chemical analysis (atom probe tomography)
  - Tribology
  - Micro- and nanomechanical testing
- Challenge-based learning
  - Development and training of competences by solving defined problems related to functional materials and materials systems, including their manufacturing, characterization, testing and degradation, based on the existing background of scientific literature

Presentation of developed problem-solving strategies and defense of the presented solutions

Evaluation - Examination*

Assessment of the module is done by continuous evaluation. Within parts 1 and 2, assessment will take place within 30-min exams, where the students should demonstrate that they have obtained the required skills and competences in functional materials systems and their manufacturing. For part 3, a mandatory attendance of 80 % is needed, in addition to submission of experimental protocols and reports. Within part 4, a case study on a selected functional materials system needs to be prepared, presented and defended.

The grades reached in all four parts contribute with equal shares to the overall grade of the module.

Module Details	Module Number*	425.206

Grading scheme*

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The teaching format for parts 1 and 2 is a frontal lecture supported by Moodle. Part 3 included demonstration and experiments performed in the laboratory. Part 4 involved problem-based learning, where a defined case study on a selected functional materials system needs to be prepared and presented.

Learning material and required equipment

Lecture notes are provided via Moodle.

A laptop/tablet with internet access is a must for completing the module.

Literature*

N.W. Ashcroft, N.D. Mermin, Solid State Physics, Saunders College Publishing, Forth Worth, 1976

M. Schwartz (ed.), Smart Materials, CRC Press, Boca Raton, 2009

Th. Klooster, Smart Surfaces, Birkhäuser, Basel, 2009

M.O. Speidel, Materials in Medicine, vdf, Zürich, 1998

N. Maluf, K. Williams, An Introduction to Microelectromechanical Systems Engineering, Artech House, Boston, 2004

N. Schalk, M. Tkadletz, C. Mitterer, Hard coatings for cutting applications: physical vs. chemical vapor deposition and future challenges for the coatings community, Surface and Coatings Technology 429 (2022) 127949. DOI: 10.1016/j.surfcoat.2021.127949

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Fundamental key knowledge, skills and competences for engineers (mathematics, physics, chemistry, technical mechanics); knowledge, skills and competences in digital sciences and statistics; materials science of metals, ceramics, semiconductors and polymers; quantum mechanics and solid state physics; fundamentals of materials technology; materials characterization and testing with a level corresponding to a Bachelor degree.

Remarks*

n/a

Core Module
Physics of Materials

Module block: Physics and Mechanics of Materials

Module Details		Module Number*	430.902
Organization*	Chair of Materials Physics		
Organization ID	430		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER		
Deputy Head of Module	Dipl.-Ing. Dr.mont. Anton HOHENWARTER		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER, Univ.-Prof. assoz.Prof. Dr. Jozef KECKES, Mag. et Dr.rer.nat. Florian SPIECKERMANN, Dipl.-Ing. Dr.mont. Andrea BACHMAIER		
Abstract	This module deals with selected chapters of materials physics, for example the quantum mechanical description of optical and thermal properties, diffusion, as well as important aspects of surface physics. This content is covered both in lecture form and supplemented with seminar work.		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☐ WS	☒ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	3		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	90		
Hours of face-to-face or online teaching	35	**of which attendance is mandatory**	80%

Module Details	Module Number*	430.902

Module Description

The module consists of a theoretical part (Part 1) and a seminar part (Part 2)

Part 1: For the theoretical part attendance is not mandatory.

Part 2: Successful completion of this part requires to give a presentation on a topic defined at the beginning of the module and also requires a minimum attendance of the seminar of 80% of all units.

Both parts have to achieve a minimum of 50% of the maximum achievable points.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the module, students have acquired the following knowledge, skills and responsibilities:

(i) Specialized knowledge on solid state physics to interpret thermal and optical properties as well as in the field diffusion.

(ii) Employing In-depth knowledge in the field of surface and interface physics

(iii) Design an independent and critical debate of modern materials topics, including use of adequate teaching and presentation techniques.

(iv) Select strategies for structural optimization of modern materials and material systems by microstructural design.

(v) Critical judgement of knowledge issues in the field of material physics properties of advanced materials and material systems, including future potentials and current limits.

Contents*

Within this module selected aspects of Materials Physics are discussed in lecture form and complimented with a seminar work where advanced material physical topics, e.g.: mechanical, electrical and magnetic effects at small dimensions or for nanostructured materials are presented, discussed and interpreted by students. The course covers:

(i) Atomistic and quantum mechanical theory of the optical properties of metals and insulators, thermal properties, phonons, thermal expansion and diffusion

(ii) Geometry and electronic structure of liquid and solid surfaces

(iii) Description of the Interaction of surfaces with media (adsorption/wetting and desorption/dewetting)

(iv) Segregation to surfaces and interfaces, segregation and adsorption of interacting atoms, embrittlement phenomena of grain and phase boundaries

Module Details	Module Number*	430.902

Evaluation - Examination*

Part 1: The theoretical part, where attendance is not mandatory, will be assessed by a 120-minute written exam. A minimum of 50% of the maximum achievable points is necessary to pass the exam.

Part 2: Successful completion of the module requires a minimum attendance of the seminar of 80% of all units, as well as a positive assessment of the seminar presentation.

Both parts have to achieve a minimum of 50% of the maximum achievable points.

Grading scheme*

The overall grade is determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The module consists of lectures complimented with a seminar work where advanced material physical topics are discussed and presented within the course group.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

R.E. Hummel: Electronic Properties of Materials (Springer)

G. Gottstein: Physical Foundations of Materials Science (Springer)

P.A. Tippler: Physik (Springer) (in German)

Ch. Kittel: Introduction to Solid State Physics (Wiley)

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Basics of solid state physics on Bachelor level, corresponding to profound knowledge of the lectures Physics I, Physics II, Physics III VU and Materials Physics I as taught at Montanuniversität Leoben.

Remarks*

n/a

Core Module
Materials Technology II

Module block: Materials Technology

Module Details		Module Number*	420.269
Organization*	Chair of Physical Metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Ronald SCHNITZER		
Deputy Head of Module	Ao.Univ.-Prof. Dipl.-Ing. Dr.mont. Gregor MORI		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER, Dipl.-Ing. Dr.techn. Gerhard POSCH		
Abstract	This module is dedicated to the fundamentals of corrosion, the types of corrosion attack, the corrosion properties of metallic and non-metallic materials and corrosion protection measures. Furthermore, powder metallurgy is covered, including powder production, characterization and preparation, as well as the theory and practice of sintering. In addition, the methods and technologies of joining of the various material classes are covered.		

General Data		
Module level	Master	
Language*	English	
Recommended semester*	☒ WS	☐ SS
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)
Contact hours*	4	
ECTS credits*	5	
Participation quota*	☒ no	☐ yes

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	0%

Module Details	Module Number*	420.269

Module Description

The module consists of three parts. The first one covers to the fundamentals of corrosion, the types of corrosion attack, the corrosion properties of metallic and non-metallic materials and corrosion protection measures. The second one deals with powder metallurgy, including powder production, characterization and preparation, as well as the theory and practice of sintering. The third part covers the methods and technologies of joining of the various material classes.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

<u>Learning outcomes*</u>

Upon successful completion of the module, students will be able to:

(i) determine and evaluate different corrosion mechanisms,

(ii) interpret results from corrosion tests,

(iii) apply advanced knowledge of powder metallurgy manufacturing methods and link the theory and practice of sintering,

(iv) apply specialized problem-solving skills to the manufacture, structure and properties of PM materials,

(v) develop concepts for welding and joining techniques.

Contents*

The course will cover

(i) Corrosion

(ii) Powder Metallurgy

(ii) Joining and Welding

Evaluation - Examination*

The successful completion of the module requires that the combined result of the tests of the three aforementioned parts be positive.

The first test covers the content of (i) Corrosion and is done as an oral exam. The second test is on the content of (ii) Powder Metallurgy and is done as written exam. Third test covers the content of (iii) Joining and Welding and is done as written exam.

The overall percentage (P) is determined by the following share of each parts:

P = 0,6*(i) + 0,2*(ii) + 0,2*(iii)

In sum a minimum of 50% of the maximum achievable points is necessary to past the module.

If part (i) is negative, the assessment can be repeated once.

Module Details	Module Number*	420.269

Grading scheme*

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Comprehensive knowledge and skills for Bachelor engineers (mathematics, physics, chemistry, technical mechanics, thermodynamics, metallic materials technology).

Remarks*

n/a

Core Module
Data-driven Materials Design

Module block: [Data-driven Materials Design]

Module Details		Module Number*	420.271
Organization*	Chair of physical metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.techn. Lorenz ROMANER		
Deputy Head of Module	Univ.-Prof. Dipl.-Ing. Dr.techn. Clara SCHUECKER		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.techn. Lorenz ROMANER, ao. Univ. Prof. Dr. Peter SUPANCIC, Dipl.-Ing. Dr.mont. Christian SARINGER.		
Abstract	This module is dedicated to teaching the basic knowledge and methods required for the analysis and machine learning of of data in materials science using scripting with Python. The module consists of lectures, labs and homework and provides the theoretical foundations as well as the practical aspects of data-driven methods in materials science		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒ WS	☐ SS		
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)		
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒ no	☐ yes		

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	50%

Module Details	Module Number*	420.271

Module Description

The course covers:

i) Materials data and materials data repositories, FAIR data principles

ii) Concepts of statistics and statistical learning, machine learning algorithms including linear models, decision trees, Gaussian process regression and neural networks

iii) Python syntax and basics of programming

iv) (Semi-)Automatic handling of large amounts of data.

v) Relevant scientific python libraries such as Numpy, Scipy, SymPy, Pandas and Sklearn.

vi) Derivation and integration of data (numerical and analytical).

vii) Producing of scientific figures and animations using matplotlib.

viii) Construction of data-driven models to describe materials phenomena and data.

ix) Application of Monte Carlo methods to model populations

x) Fracture statistics modelling

xi) Applications and own lab exercises.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After positive completion of the module, students will:

(i) know basic syntax and datatypes in Python.

(ii) name data principles and challenges associated with materials data and explain them with examples.

(iii) Extract data from materials databases.

(iv) use the most important software applications for scientific data evaluation with Python

(v) write scripts for the automatic evaluation of large data sets to be displayed in theses and scientific publications.

(vi) describe important machine learning algorithms used in materials science and judge their suitability for a specific application.

(vii) be able to work out representative examples that show applications of machine learning to predict materials properties and behavior.

Contents*

This module conveys fundamental knowledge and methods required for the analysis and for machine learning of data from materials science employing scripting with a commonly used programming language

Module Details	Module Number*	420.271

Evaluation - Examination*

Successful completion of the module requires a minimum attendance of 50% of all face-to-face units. Furthermore, the following tasks will be graded:

i) an assessment in form of a 25 min written exam on the Moodle platform

ii) home-work, that students submit on the Moodle platform

iii) An own coding project that is presented to the other students in the final units.

All three parts need to achieve a minimum of 50% of the maximum achievable points.

Grading scheme*

After fulfilling the requirement of minimum attendance and after positive completion of all three parts (i) (ii) and (iii), the achieved total percentage is calculated as a weighted average of the percentages p1 and p2 obtained for part (i) and part (ii), respectively.

$P = 0.25*p1 + 0.5*p2 + 0.25*p3$

The overall grade is then determined according to the following grading scheme:

$87.5\% \leq P \leq 100.0\%$:	Very good (1)
$75.0\% \leq P < 87.5\%$:	Good (2)
$62.5\% \leq P < 75.0\%$:	Satisfactory (3)
$50.0\% \leq P < 62.5\%$:	Sufficient (4)
$0.0\% \leq P < 50.0\%$:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundations are taught in classical lecture style using a projector and a chalkboard.

In the lab part the theoretical knowledge is fostered and applied to simple example problems using Python under the guidance of a tutor. The practical skills in python scripting are then strengthened with homework assignments.

Learning material and required equipment

Lecture notes are provided on moodle. A laptop/tablet is a must for completing the module together with a running python installation.

Literature*

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2021). An introduction to statistical learning: With applications in R (2nd ed.). Springer.
Murphy, Kevin P. *Machine Learning: A Probabilistic Perspective*. Cambridge, MA: MIT Press, 2012.

Prerequisite courses / modules for registration

None

Expected previous knowledge*

Basic knowledge of materials and their properties as well as experience with a programming language

Remarks*

n/a

Core Module
Science and Responsibility

Module block: Science and Responsibility

Module Details		Module Number*	425.208
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER		
Deputy Head of Module	Univ.-Doz. Dipl.-Ing. Dr. Nina Schalk		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Christian MITTERER, Priv.-Doz. Dipl.-Ing. Dr.mont. Nina SCHALK, Dipl.-Ing. Dr.mont.Fabian KONSTANTINIUK		
Abstract	Within this module the basic key knowledge, skills and competences necessary to conduct scientific research with the rigorous responsibility required to meet the standards of scientific validity and ethical norms are taught and trained. The module accompanies the Master's thesis.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒	WS	☒	SS
Module type*	☒	**MI** (cont. evaluation)	☐	**MN** (single examination)
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒	no	☐	yes

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	80%

Module Details	Module Number*	425.208

Module Description

The module consists of two parts:

Part 1 focuses on training the basic skills and competences necessary to conduct scientific research, including literature review, definition of research questions, scientific writing and presentation of scientific findings, correct citations and ethics. This part will be done in class-room lessons supported by case studies and accompanied by multiple homework assignments. In addition to the mandatory homework, an 80 % of mandatory attendance is needed for this unit. This part is supported by Moodle.

Part 2 will be offered at the Chair where the master thesis is done, where students need to solidify the skills and competences gained in part 1 by conducting the literature review for the master thesis of choice, by the definition of research questions and a suitable methodology, and by writing, presenting and defending an exposé for the master thesis. Guidance for this part is done by the supervisor of the master thesis. After successfully passing both parts, students are ready to start the experimental/theoretical research work needed for the master thesis.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the lecture, students have acquired the following knowledge, skills and competences:

- Highly specialized knowledge on conducting complex scientific research including the definition of research questions, survey and critical evaluation of scientific literature, designing suitable research program for the master thesis, critical evaluation and presentation of obtained findings and results, scientific story-telling, citation of literature.
- Critical awareness of good scientific conduct, correct citations and avoidance of plagiarism, providing a solid foundation for good scientific practice.
- Specialized skills and responsibilities for the design, preparation and defense of scientific theses and scientific publications, which present and discuss the findings and conclusions of complex research and development tasks.

Module Details	Module Number*	425.208

Contents*

Within this module, the fundamental key knowledge, skills and competences necessary for conducting scientific research with the rigorous responsibility needed to satisfy standards of scientific validity and ethical norms will be communicated and trained. The module covers the following topics:

- Literature survey and critical evaluation of publications to demonstrate the existing state of the art
- Definition of research questions
- Scientific writing, structure of scientific theses and publications
- Presentation of results, design of tables and figures
- Correct citations
- Artificial intelligence in scientific research
- Ethics and plagiarism
- Review and revision of theses and manuscripts
- Presentation and defense of scientific findings
- Workshop and case studies
    - Critical evaluation of published papers – how to identify a well-written and meaningful paper?
    - Scientific debates – asking questions, presenting arguments, defending own points of view
    - Story-telling and scientific writing
    - Use of artificial intelligence in scientific research
    - Design of figures and tables
    - Oral presentations and defense of obtained findings
- Case study master thesis
    - Literature review
    - Definition of research questions
    - Definition of methodology
    - Exposé writing and presentation

Evaluation - Examination*

Assessment of the module is done by continuous evaluation. For part 1, a mandatory attendance of 80 % is needed, in addition to submission and evaluation of the homework. Part 2 is completed by the successful presentation and defence of the exposé for the master thesis. Both parts need to be successfully completed. The grade reached in both parts contributes with equal shares to the overall grade of the module. If one of parts is not passed, the assessment can be repeated once.

Grading scheme*

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Module Details	Module Number*	425.208

Teaching and learning methods*

The teaching format for part 1 is a frontal lecture enriched by interactive case studies, readings, and homework lessons. This part is supported by Moodle.

Part 2 is done in individual lessons with the supervisor of the master thesis, who will guide the student towards preparation of the exposé of the master thesis.

Learning material and required equipment

Lecture notes are provided via Moodle.

A laptop/tablet with internet access is a must for completing the module.

Literature*

Gary Provost, 100 Ways to Improve Your Writing, Mentor, New York, 1985.

Claus Ascheron, Die Kunst des wissenschaftlichen Präsentierens und Publizierens: Ein Praxisleitfaden für junge Wissenschaftler, Elsevier Spektrum Akademischer Verlag, München, 2006.

Claus Ascheron, Angela Kickuth, Make Your Mark in Science: Creativity, Presenting, Publishing, and Patents, a Guide for Young Scientists, John Wiley, 2004.

Mike Ashby, How to Write a Paper, University of Cambridge, Cambridge, 2021. https://www.ansys.com/content/dam/amp/2021/august/webpage-requests/education-resources-dam-upload-batch-2/how-to-write-a-paper-BOKHOWEN21.pdf

Timothy Skern, Writing Scientific English. A Workbook, Verlag facultas, Wien, 2019. https://elibrary.utb.de/doi/book/10.36198/9783838550664 (e-book available at MUL, VPN required from outside)

Thomas S. Kuhn, Ian Hacking, The Structure of Scientific Revolutions, University if Chicago Press, Chicago, 1962.

Raymond Boxman, Edith Boxman, Communicating Science - A Practical Guide for Engineers and Physical Scientists, World Scientific, Singapore, 2017 (videos also available on Youtube).

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Fundamental key knowledge, skills and competences for engineers (mathematics, physics, chemistry, technical mechanics); knowledge, skills and competences in digital sciences and statistics; fundamentals of materials science of metals, ceramics, semiconductors and polymers; First experience in conducting scientific research (e.g. literature research, bachelor thesis) is recommended.

Remarks*

n/a

Profile Module
Materials and Processes in Microelectronics

Module block: Elective Modules

Module Details		Module Number*	425.210
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Ing. assoz.Prof. PhD Rostislav DANIEL		
Deputy Head of Module	Priv.-Doz. Dr. Dipl.inz.elektr. Aleksandar MATKOVIC		
Contributor*	Ing. assoz.Prof. PhD Rostislav DANIEL, Priv.-Doz. Dr. Dipl.inz.elektr. Aleksandar MATKOVIC		
Abstract	This module introduces students to the scientific foundations and technological principles that form the basis of modern micro- and nanoelectronics. Emphasis is placed on the interplay between material properties and fabrication techniques, enabling a deeper understanding of how electronic components are designed and realized. Through hands-on experiments, data evaluation, and problem-based learning, students develop the ability to link theoretical knowledge with practical implementation. The module fosters analytical thinking and prepares students to address the challenges of material selection, process integration, and scaling in electronic device manufacturing.		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☐ WS	☒ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	4		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	45%

Module Details	Module Number*	425.210

Module Description

This module provides advanced knowledge and practical skills in the design of high-performance micro- and nanoelectronic devices, focusing on the properties and applications of semiconductor and non-semiconductor materials. Key topics include wafer technologies, fabrication processes, MOS-FET technology, discrete and integrated interconnects, dielectric materials, and passive components, with an emphasis on addressing current challenges associated with miniaturization and exploring innovative solutions in modern microelectronics.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully completing the module, students will be able to list and explain the fundamental application concepts of non-semiconductor and semiconductor materials in modern microelectronic components and devices, describe the technological processes and materials produced, and apply these principles to case studies. They will analyze and critically assess current knowledge issues, trends, and limitations in microelectronics, formulate potential advancements and innovative approaches, and design strategic approaches and future technologies in nanoelectronics. In addition, students will be competent in implementing these strategic approaches, evaluating their effectiveness and potential impact, and creating novel solutions in the field.

Contents*

Within this module, the fundamental key knowledge, skills and competences necessary to design high-performing micro- and nanolectronic components and basic devices will be gained. The module covers the following topics:

- Background in semiconductors and solid state physics (relation of the band structure with electrical and optical properties) with lab experiments 1
- Fabrication of semiconducting single crystals (overview of wafer technologies)
- Field modulation in semiconductors (basics of a MOS-FET)
- Challenges associated with miniaturization of microelectronic components and devices
- Fabrication of miniaturized components and devices - deposition, masking, lithography, etching, passivation, metallization (Very/Ultra Large-Scale Integration)
- Interconnects, seed layers, liners, diffusion barriers
- Dielectric materials in microelectronics - low-k and high-k dielectrics
- Semiconducting materials beyond silicon (III-V and van der Waals semiconductors)
- Lab experiments 2: CVD growth of a 2D MoS2 semiconductor
- Discrete and integrated passive components - resistors, capacitors
- Lab experiments 3: Characterization of a thin metallic film (data analysis)
- GaN and SiC based technologies
- Presentation of developed problem-solving strategies and defense of the presented solutions based on problem-based learning (development and training of competences by solving defined problems in micro- and nanoelectronics based on the existing background of scientific literature)

Module Details	Module Number*	425.210

Evaluation - Examination*

Assessment is based on continuous evaluation, including self-assessment tests in Moodle, as well as submitted experimental protocols, project work, and written reports. Students are expected to demonstrate the acquisition of relevant knowledge, skills, and competences in understanding and applying materials, processes, and fundamental device principles in micro- and nanoelectronics. All evaluated components contribute to the final module grade.

Grading scheme*

The overall grade is then determined according to the following grading scheme:

$87.5\% \leq P \leq 100.0\%$: Very good (1)

$75.0\% \leq P < 87.5\%$: Good (2)

$62.5\% \leq P < 75.0\%$: Satisfactory (3)

$50.0\% \leq P < 62.5\%$: Sufficient (4)

$0.0\% \leq P < 50.0\%$: Not sufficient (5)

Teaching and learning methods*

The module combines guided self-study with interactive in-person sessions and hands-on experimental work. Students begin by independently studying selected topics using lecture materials and practical examples provided via Moodle. These are followed by group discussions aimed at deepening understanding, fostering creative thinking, and applying knowledge in small project-based tasks. In addition, students will either conduct experiments themselves or evaluate provided experimental data to gain insights into scientific methods and research-oriented problem solving. Each learning unit concludes with a self-assessment test in Moodle, helping students identify areas for improvement. Additional materials, such as short articles and scientific papers, are available in Moodle for those who wish to explore specific topics in greater depth.

Learning material and required equipment

Lecture notes and supporting materials will be provided via Moodle.

For participation in in-person sessions, experiments, and data evaluation, students are required to bring a laptop or tablet with internet access.

Literature*

Relevant literature, including scientific papers, short scientific articles, and references to key publications, will be provided via Moodle and included in the lecture slides as supporting material.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Fundamental key knowledge, skills and competences for engineers in mathematics, physics and chemistry. Solid basics of materials and solid state physics (materials science of metals, ceramics and semiconductors). Basic knowledge and skills in digital sciences and statistics and in the field of electrical engineering and electronics is an advantage.

Remarks*

n/a

Profile Module
Atomistic Materials Modelling

Module block: Elective Modules

Module Details		**Module Number***	**420.270**
Organization*	Chair of physical metallurgy		
Organization ID	420		
Module Manager	Priv.-Doz. Mgr. PhD David HOLEC		
Deputy Head of Module	Univ.-Prof. Dipl.-Ing. Dr.techn. Lorenz ROMANER		
Contributor*	Priv.-Doz. Mgr. PhD David HOLEC, Univ.-Prof. Dipl.-Ing. Dr.techn. Lorenz ROMANER, Priv.-Doz. Mag.rer.nat. Dr.rer.nat. Markus HARTMANN, Dr.rer.nat. Daniel SOPU		
Abstract	This module covers calculations of electronic structure (incl. density functional theory), molecular dynamics and Monte Carlo methods. They are demonstrated on structural, mechanical, thermal and electronic properties, diffusion and ordering phenomena and defects such as dislocations and grain boundaries. Numerous practical exercises are aimed at learning how to apply these methods in materials research.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☐	WS	☒	SS
Module type*	☒	**MI** (cont. evaluation)	☐	**MN** (single examination)
Contact hours*	5			
ECTS credits*	5			
Participation quota*	☒	no	☐	yes

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	25%

Module Details	**Module Number***	**420.270**

Module Description

The module consists of a series of frontal lectures and practical exercises.

The lectures start with a general introduction to materials modelling, focusing on atomistic methods. They will then go on to discuss methodological aspects related to interatomic potentials, molecular dynamics and the Monte Carlo method. Subsequent lectures cover material science phenomena that can be addressed using these techniques, including phonons, defects with a strong focus on interfaces and grain boundaries, and solid solutions, phase stability, ordering and segregation. At the end of this part, the students take the first oral examination.

The second part of the theoretical lectures deals with electronic structure methods. Students are introduced to the nearly free electron gas, tight-binding and linear combination methods of atomic orbitals, the Hartree and Hartree-Fock approximations, and density functional theory, including the pseudopotential and all-electron methods. Applications of the techniques to the prediction of electronic structure and optical properties of materials will be given. This block concludes with the second oral examination.

Attendance at these theoretical lectures is not compulsory but is strongly recommended.

Lectures will be accompanied by exercises throughout the semester. These will provide hands-on experience in the technicalities of individual techniques (molecular statics and dynamics, Monte Carlo, density functional theory) applied to diverse problems including structural properties, diffusion, ordering, magnetic transitions, thermodynamics, surface and interfacial structures, thermodynamics of grain boundary segregation, elasticity, electronic structure and optical properties. Exercises will be carried out using Jupyter notebooks. An attendance of 80% during the exercises is required.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

Upon successful completion of the module, students will:

(i) understand state-of-the-art atomistic modeling methods such as DFT (density functional theory), MD (molecular dynamics) and MC (Monte Carlo simulation), and be able to critically assess their applications and limitations,
(ii) have gained practical experience in applying these methods to current problems in materials physics and physical metallurgy. This includes the creation of simulation models, their execution with scientific software, the evaluation of the calculations and the critical interpretation of the results,
(iii) have acquired highly specialized knowledge of the interpretation of the electronic structure of materials, structural, thermal and mechanical properties, phonons, defects such as dislocations and interfaces as well as thermokinetic models for diffusion and segregation,
(iv) can use scientific Python tools for calculations and data processing in cloud environments.

Module Details	Module Number*	420.270

Contents*

This module provides a comprehensive overview of atomistic materials modeling, covering calculations of electronic structure (incl. Density Functional Theory), molecular dynamics and Monte Carlo methods. They are demonstrated on structural, mechanical, thermal and electronic properties, diffusion and ordering phenomena and defects such as dislocations and grain boundaries. Numerous practical exercises accompanying the theoretical lectures, are aimed at learning how to apply these methods in materials research.

- Atomistic modeling
  - Overview of techniques
  - Bonding in solids and interatomic potentials
  - Monte Carlo method
  - Molecular dynamics
  - Phonons, phonon thermodynamics
  - Coincidence site lattice, interfaces
  - Grain boundaries, segregation
  - Solid solutions, ordering, diffusion
- Electronic structure methods
  - (Nearly)-Free electron gas
  - Tight-binding, LCAO
  - Electronic band structure
  - Hartree method, Hartee-Fock method
  - Density Function Theory
  - Plane waves, Pseudopotentials, Augmented plane-wave method
- Optical properties

Evaluation - Examination*

Part 1: two oral exams:

oral exam 1: Atomistic modeling; weight: 30 %

oral exam 2: Electronic structure methods; weight 30 %

Part 2: handing in solutions of hands-on practical exercises; weight 40 %

graded as percentage of the total number of achievable points:

Grading scheme*

Overall grade: All parts (2 oral exams + exercises) must be successfully passed. The final grade is will be a weighted rounded average of the individual grades.

87.5% ≤ P ≤ 100.0%: Very good (1)

75.0% ≤ P < 87.5%: Good (2)

62.5% ≤ P < 75.0%: Satisfactory (3)

50.0% ≤ P < 62.5%: Sufficient (4)

0.0% ≤ P < 50.0%: Not sufficient (5)

Module Details	Module Number*	420.270

Teaching and learning methods*

The theoretical units are taught in the classic lecture style with a projector and blackboard.

The hands-on sessions involve interactive Jupyter notebooks with the problem submission via Moodle.

Learning material and required equipment

Lecture notes are provided. A laptop/tablet with internet connection withing university network (or with a VPN connection) is required for completing the exercises.

Literature*

- LeSar, Richard. Introduction to computational materials science: fundamentals to applications. Cambridge University Press, 2013.
- Lee, June Gunn. Computational materials science: an introduction. CRC press, 2016.
- Dove, Martin T. Structure and dynamics: an atomic view of materials. Vol. 1. Oxford University Press, 2003.
- Cai, Wei, and William D. Nix. Imperfections in crystalline solids. Cambridge University Press, 2016.
- Singleton, John. Band theory and electronic properties of solids. Vol. 2. OUP Oxford, 2001.
- Kittel, Charles, and Paul McEuen. Introduction to solid state physics. John Wiley & Sons, 2018.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Basic knowledge of thermodynamics, statistical physics and quantum mechanics. Basic knowledge of crystallography. Basic knowledge of programming.

Remarks*

n/a

Profile Module
Atomic-scale Materials Characterisation

Module block: Elective Modules

Module Details		Module Number*	430.904
Organization*	Chair of Materials Physics		
Organization ID	430		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER		
Deputy Head of Module	Dipl.-Ing. Dr.mont. Michael TKADLETZ		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER, Dipl.-Ing. Dr.mont. Markus ALFREIDER, Dipl.-Ing. Dr.mont. Anton HOHENWARTER, Dipl.-Ing. Dr.mont. Anna JELINEK, Priv.-Doz. Dr. Zaoli ZHANG		
Abstract	In this module, the methods and necessary preparations for assessing the atomic structure of materials, which is decisive for their mechanical and functional properties, are reviewed. Selected examples will be analysed and discussed by the participants.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☐ WS	☒ SS		
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)		
Contact hours*	3			
ECTS credits*	5			
Participation quota*	☒ no	☐ yes		

Expected Workload			
Total hours	125		
Hours of self-study	90		
Hours of face-to-face or online teaching	35	**of which attendance is mandatory**	80%

Module Details	Module Number*	430.904

Module Description

The module consists of four parts:

In part 1, the technical fundamentals required for the understanding and use of AFM and SPM will be explained and discussed. Part 2 focuses on atom probe tomography, including specimen preparation and data interpretation, and will be accompanied with practical exercises at the Chair of Functional Materials and Material Systems. Part 3 concerns the transmission electron microscope, addressing the fundamentals and advanced analyses methods of this technique. In addition, the participants will also get some demonstration at the Chair of Materials Physics and some hands on experience. In part 4, the participants write a report in the form of an outline for a scientific research question, where some or all of the presented investigation methods are necessary in a complimentary approach to address the question at hand.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the module, students have acquired the following knowledge, skills and responsibilities:

• Differentiate the basic surface and sample preparation strategies for AFM, SPM, TEM, and APT specimens

• Distinguish fundamental principles of image formation in transmission electron microscopy and interpret them with examples

• Argue working modes and create analysis strategies of atom probe tomography

• Extract, evaluate and interpret information from atomistic data sets

• Plan complementary techniques for a comprehensive atomistic information

• Assemble theoretical crystal structure information to experimental observations

• Design a presentation of a selected case that connects atomistic material structure to outstanding resultant properties in materials science.

Contents*

Within this module the methods and necessary preparation for assessing the atomic structure of materials decisive for their mechanical and functional properties are addressed and compared, and selected examples analyzed and discussed by the participants. The course covers:

• Surface structures, crystal facets, and their assessment by atomic force and scanning tunneling microscopy

• Image formation and defect analysis and interpretation by transmission electron microscopy

• High resolution transmission electron microscopy

• Localized sample preparation for transmission electron microscopy

• 3D chemical analysis of defects using atom probe tomography

• Site specific atom probe tomography specimen preparation

• Correlation between atomistic chemical and structural information

• Applications of machine learning to atomistic materials data

• Student assessment of selected example linking atomistic structure to material properties

Module Details	Module Number*	430.904

Evaluation - Examination*

Successful completion of the module requires a minimum attendance of the lab exercises of 80% as well as a positive assessment on continuous tests after the different module parts. Part 4 requires a positive evaluation of the report.

Grading scheme*

After positive completion of part 1-4 the total percentage is calculated as a weighted average of the percentages of Part 1-4, respectively.

P = 0.1*Part 1 + 0.4*Part 2 + 0.4*Part 3 + 0.1*Part 4

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The teaching format for parts 1-3 is primarily a frontal lecture, supported by a Moodle course. In addition, Part 2 and 3 include demonstrations and experiments performed in the laboratory. Part 4 involves problem-based learning, where a defined case study on a selected materials science problem with emphasis on the used techniques is outlined and described in a written report.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

D.B. Williams, C.B. Carter: Transmission Electron Microscopy (Springer)

B. Gault, M.P. Moody, J.M. Cairney, S.P. Ringer: Atom Probe Microscopy (Springer)

D.J. Larson, Local Electrode Atom Probe Tomography: A User's Guide (Springer)

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Demonstrate comprehensive knowledge of materials, microstructures, and infer their influence on mechanical properties. Express fundamental understanding of material characterization methods.

Remarks*

n/a

Profile Module
Materials in Extreme Environments

Module block: Elective Modules

Module Details		Module Number*	420.268
Organization*	Chair of Physical Metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Ronald SCHNITZER		
Deputy Head of Module	Univ.-Prof. Dr. Raul BERMEJO MORATINOS		
Contributor*	Prof. Dipl.-Ing. Dr. mont. Peter HOSEMANN, Dipl.-Ing. Dr. mont. Max SILLER, Ao.Univ.-Prof. Dipl.-Ing. Dr.mont. Tanja LUBE, Priv.-Doz. DI Dr. Gernot ORESKI		
Abstract	This module deals with the use of materials under extreme conditions, such as radiation, very high temperatures and/or aggressive media. The degradation of the properties of plastics, ceramic coating systems (such as TBCs) and new ceramic concepts for extreme temperatures and operating conditions, as well as materials for nuclear applications and refractory metals will be taught.		

General Data		
Module level	Master	
Language*	English	
Recommended semester*	☐ WS	☒ SS
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)
Contact hours*	5	
ECTS credits*	5	
Participation quota*	☒ no	☐ yes

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	20%

Module Details	**Module Number***	**420.268**

Module Description

This module deals with the use of materials under extreme conditions, such as radiation, very high temperatures and/or aggressive media. The module consists of three parts. The first one covers the degradation of the properties of ceramics and plastics. The second one deals with materials for nuclear applications and the third part covers refractory metals.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

Upon successful completion of the module, students will be able to:

(i) evaluate the material behavior at radiation, high and/or low temperatures,

(ii) select refractory metals for their application and materials for nuclear use,

(iii) design new test setups for extreme environments,

(iv) assess the degradation behavior of plastics with highly specialized knowledge.

(v) evaluate the mechanical behavior of ceramic thermal barrier coatings (TBC) and high entropy ceramics (HEC) for high temperature applications

Contents*

The course will cover

(i) degradation of plastics

(ii) materials for nuclear applications

(ii) refractory metals for high temperatures

(iv) Thermal Barrier Coatings (TBCs): material systems, structure, properties, characterization, applications

(v) Special ceramics for extreme conditions: Ultra-High-Temperature Ceramics, High Entropy Ceramics, MAX-Phases: material systems, basic principles, processing, properties

Module Details	Module Number*	420.268

Evaluation - Examination*

Successful completion of the module requires a minimum attendance of 20% and a positive assessment on the tests or presentations of each part mentioned above.

In sum a minimum of 50% of the maximum achievable points of all test is necessary to pass the module.

There is also the option to do the module non-immanent, that means without the requirement to fulfil the minimum attendance. The assessment is then done with one single examination on all parts together. That is the unsupported track and has to be requested when registering for the course at the beginning.

Grading scheme*

After fulfilling the requirement of minimum attendance the overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0%:	Very good (1)
75.0% ≤ P < 87.5%:	Good (2)
62.5% ≤ P < 75.0%:	Satisfactory (3)
50.0% ≤ P < 62.5%:	Sufficient (4)
0.0% ≤ P < 50.0%:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Comprehensive knowledge and skills for Bachelor engineers (mathematics, physics, chemistry, technical mechanics, thermodynamics, metallic materials technology)..

Remarks*

n/a

Profile Module
Hard Materials and Composites

Module block: Elective Modules

Module Details		Module Number*	410.006
Organization*	Chair of Structural and Functional Ceramics		
Organization ID	410		
Module Manager	Ao.Univ.-Prof. Dipl.-Ing. Dr. mont. Tanja LUBE		
Deputy Head of Module	Univ.-Prof. Dr. Raul BERMEJO MORATINOS		
Contributor*	Ao.Univ.-Prof. Dipl.-Ing. Dr. mont. Tanja LUBE, Univ.-Prof. Dr. Raul BERMEJO MORATINOS, Dipl.-Ing. Dr. mont. Thomas KLÜNSNER, Dipl.-Ing. Dr. mont. Thomas WEIHRATHER		
Abstract	This module teaches the fundamentals of the technology of ceramic matrix composites, ceramic laminate architectures and hard metals as well as their components. Materials science fundamentals and material mechanics principles for understanding the mechanical and functional properties of these materials are explained and analyzed. Typical areas of application are discussed.		
General Data			
Module level	Master		
Language*	English		
Recommended semester*	☐ WS	☒ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	4		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	
Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	30%
Module Description			

Module Details	Module Number*	410.006

The module consists of four topical parts:

Part 1 gives an overview on Ceramic Matrix Composites, their technology, their properties and their applications.

Part 2 deals with Laminated Ceramic Architectures, their technology, mechanical behaviour and applications.

Part 3 is focused on Hard Materials.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After positive completion of the course, the students have advanced knowledge, skills, and competences of the material aspects of composite materials for applications at different loading conditions. They will be able to

- Critically assess and justify the choice of specific materials for selected applications,
- interpret the performance of ceramic matrix composites, laminates, and hard metals based on process- and material-related characteristics,
- Conceptually design and perform complex research and develop new strategic approaches,
- Identify potentials for material innovations in the field of ceramic matrix composites and hard metals based on critical awareness of existing knowledge.

Contents*

- Composites: types, basic principles of mechanical behavior
- Ceramic Matrix Composites - constituents, processing, mechanical behavior, applications:
  - Reinforcements: particles, whiskers, anorganic and ceramic fibers: types, processing, properties
  - Processing of particle and continuous fiber reinforced composites: relevant process characteristics of the main processing technologies (manual processes, liquid impregnation processes including preforming, pressing, laying and winding technology, pressing processes)
  - Mechanical behaviour and micromechanics of composite materials: rule of mixture, mean-field methods, toughening mechanisms, steady state cracking
  - Interface mechanics, design and technology
  - Fields of application
- Ceramic laminates: weak and strong interface laminates, residual stress design, mechanical behaviour, design, processing and characterization.
- Hard metals: material systems (WC-Co and WC-TiC, TaC, NbC, … -Co), history of hard metals, processing via the powder route, recycling, microstructure and mechanical properties, typical applications.

Module Details	Module Number*	410.006

Evaluation - Examination*

For the topics "Laminated Architectures" and "Hard Materials" assessment will take place within 60-min exams (written and/or oral) for each part, where the students should demonstrate that they have obtained the required skills and competences. (Parts A, B)

For parts "Ceramic matrix composites" and "Coatings and New Material Concepts", a case study on selected aspects of ceramic composites needs to be prepared, presented (approx. 20 min) and defended. (Part C)

The grades reached in all three parts (A, B, C) contribute with equal shares to the overall grade of the module.

Grading scheme*

The overall grade is then determined according to the following scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The theoretical foundations are taught in classical lecture style using a projector and a chalkboard supported by Moodle. Part 4 involved problem-based learning, where a defined case study on a selected ceramic system needs to be prepared and presented. The completion of the case study will require reading, literature research.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Knowledge, skills and competences at bachelor level in the field of processing of metals, ceramics, and polymers, structure-property relationships of materials, mechanical behavior of materials.

Remarks*

n/a

Profile Module
Materials for Energy

Module block: Elective Modules

Module Details		**Module Number***	**425.xxx**
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Priv.-Doz. Dipl.-Ing. Dr.mont Nina SCHALK		
Deputy Head of Module	Assoz. Prof. Dipl.-Ing. Dr.mont. Edith BUCHER		
Contributor*	Priv.-Doz. Dipl.-Ing. Dr.mont Nina SCHALK, Assoz. Prof. Dipl.-Ing. Dr.mont Edith BUCHER, Univ.-Prof. Mag. et Dr.rer.nat. Oskar PARIS		
Abstract	Within this module the significance of materials for energy conversion, storage and transport is discussed, covering structural (metals, alloys, ceramics, polymers and composites) and functional materials as well as their synthesis methods.		
General Data			
Module level	Master		
Language*	English		
Recommended semester*	☒ WS	☐ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	5		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	
Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	25 %

Module Details	Module Number*	425.xxx

Module Description

The module consists of two parts:

Part 1 gives an overview about the significance, manufacturing, design, architecture and properties of structural and functional materials for energy applications.

Part 2 involves the preparation and presentation of a case study on a selected energy related materials topic.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the lecture, students have acquired the following knowledge, skills and are able to take over project management, decisions and responsibilities:

- Categorize materials classes and synthesis methods.
- Critically judge and assess the importance of materials selection for energy conversion and storage systems.
- Formulate and design the demand profiles materials applied for different energy conversion and storage systems need to fulfill.
- Assess knowledge issues in the field of materials selection for power engineering, including future potentials and present limits of applicability.
- Devise specialized problem-solving skills required in research in the field of materials selection for power engineering to establish the basis for gaining new research findings and future materials innovations.
- Design and perform complex unpredictable research and development tasks necessitating novel strategic approaches.

Module Details	Module Number*	425.xxx

Contents*

Within this module, the fundamental key knowledge, skills and competences necessary for research and application of materials for energy will be communicated and trained. The module covers the following topics:

- Significance of materials for energy applications covering structural materials (pure metals, alloys, ceramics, polymers, composites) and functional materials
- Energy conversion – established technologies
  - Turbines for water, steam and gas
  - Nuclear energy
  - Wind energy
  - Solar energy
- Energy conversion – new technologies
  - Thermoelectric materials
  - Piezo- and triboelectric nanogenerators
  - Fuel cells and electrolysis cells
- Energy storage
  - Batteries
  - Capacitors and supercapacitors
  - Hydrogen storage
- Materials for energy transport
- CO_2 capture and storage

Presentation of developed problem-solving strategies and defense of presented solutions.

Evaluation - Examination*

Assessment of the module is done by continuous evaluation. Within Part 1, assessment will take place with three 30 min. exams. Each of these exams counts 20 % for the final mark. Within Part 2, a case study on a selected energy related materials topic needs to be prepared, presented and defended, which counts 40 % for the final mark. For the presentations and discussions of the case studies, a mandatory attendance of 80 % is required.

Grading scheme*

The overall grade is then determined according to the following scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Module Details	Module Number*	425.xxx

Teaching and learning methods*

The teaching format for Part 1 is a frontal lecture supported by Moodle. Part 2 involves problem-based learning, where a defined case study on a selected energy related materials topic needs to be prepared and presented.

Learning material and required equipment

Lecture notes are provided via Moodle.

A laptop/tablet with internet access is a must for completing the module.

Literature*

Schmiegel, Energiespeicher für die Energiewende, Hanser

Munoz-Rojas, Moya, Materials for Sustainable Energy Applications, Stanford Publishing

Smets et al., Solar Energy, UIT Cambride Ltd.

Hau, Windkraftanlagen, Springer

Goldsmid, Introduction to Thermoelectricity, Springer

Wang, Nanogenerators for Self-powered Devices and Systems, Georgia Institute of Technology, SMARTech digital repository

Van de Voorde, Hydrogen Storage for Sustainability, De Gruyter

O'Hayre et al.: Fuel Cell Fundamentals, John Wiley & Sons.

Beguin & Frackowiak, Carbons for Electrochemical Energy Storage and Conversion Systems, CRC Press, 2010.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Fundamental key knowledge, skills and responsibilities for engineers (mathematics, physics, chemistry, technical mechanics); knowledge, skills and responsibilities in digital sciences and statistics; materials science of metals, ceramics, semiconductors and polymers; quantum mechanics and solid state physics; fundamentals of materials technology; materials characterization and testing

Remarks*

n/a

Profile Module
Interfaces and Devices in Microelectronics

Module block: Elective Modules

Module Details		Module Number*	425.210
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Ing. assoz.Prof. PhD Rostislav DANIEL		
Deputy Head of Module	Priv.-Doz. Dr. Dipl.inz.elektr. Aleksandar MATKOVIC		
Contributor*	Ing. assoz.Prof. PhD Rostislav DANIEL, Priv.-Doz. Dr. Dipl.inz.elektr. Aleksandar MATKOVIC		
Abstract	This module builds practical expertise and deepens theoretical understanding in the field of micro- and nanoelectronics, with a focus on current challenges and innovative device concepts. Students engage with topics ranging from next-generation transistors and memory components to novel materials and packaging technologies. Hands-on experiments, critical data analysis, and project-based learning foster the ability to tackle real-world problems in electronic device design. The module encourages independent thinking, scientific reasoning, and a forward-looking perspective on emerging trends in the electronics industry.		

General Data		
Module level	Master	
Language*	English	
Recommended semester*	☐ WS	☒ SS
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)
Contact hours*	4	
ECTS credits*	5	
Participation quota*	☒ no	☐ yes

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	45%

Module Details	Module Number*	425.210

Module Description

This module explores advanced concepts and techniques for designing and optimizing high-performance micro- and nanoelectronic devices. Key topics include MOS-FET scaling, memory technologies, neuromorphic electronics, integrated supercapacitors, and advanced IC packaging methods. Emphasis is placed on device reliability, thermal and stress management, mechanical integrity, and cutting-edge technologies such as III-V semiconductor heterostructures and 2D van der Waals materials, aiming to provide a comprehensive understanding of innovative strategies and future trends shaping the field of microelectronics.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully completing the module, students will be able to recall and explain key concepts, advanced topics, and emerging trends at the forefront of micro- and nanoelectronics, apply this specialized knowledge to analyze current research and technologies, design strategic approaches, and develop innovative future technologies based on their own original ideas. They will also possess specialized problem-solving skills essential for research, take responsibility for designing and executing complex research and development tasks, and integrate knowledge from this module and scientific literature to perform these tasks effectively.

Contents*

Within this module, advanced knowledge, skills and competences necessary to design high-performing micro- and nanoelectronic devices are gained. The module covers the following topics:

- From International Technology Roadmap (ITRS) to International Device Roadmap for Semiconductors (IDRS): development of microelectronic materials and components
- Metal-semiconductor junctions (Schottky junctions, contact resistance)
- MOS-FET scaling technologies (from first MOS-FETs to modern Si nanoribbon FETs)
- Memory elements (SSD/flash memory, DRAM, SRAM, CCD, ReRAM), advanced ReRAM arrays, neuromorphic/synaptic electronics, MRAM
- Lab experiments 1: Measuring and modeling of 2D transistors
- Integrated super-capacitors in micro- and nanoelectronics
- Integration of microelectronic components - interconnection of components and devices at various levels of IC packaging (2D to 3D packaging)
- Reliability of micro- and nanoelectronic devices - thermal and stress management
- Lab experiments 2: Determination of thermals stress and thermal expansion coefficients of layered architectures (data analysis)
- Mechanical integrity - Testing methods and optimization approaches
- III-V semiconductor heterostructures: 2D electron gas, HEMT
- Van der Waals electronics - graphene and graphene-based electronics, 2D insulators, 2D semiconductors, 2D heterostructures, world's thinnest p-n junctions, vertical transistors
- Possible external speaker (from MUL or industry)
- Presentation of developed problem-solving strategies and defense of the presented solutions based on problem-based learning (development and training of competences by solving defined problems in micro- and nanoelectronics based on the existing background of scientific literature)

Module Details	Module Number*	425.210

Evaluation - Examination*

Assessment is based on continuous evaluation, including self-assessment tests in Moodle, as well as submitted experimental protocols, project work, and written reports. Students are expected to demonstrate the acquisition of relevant skills and competences in the design and fabrication of high-performance micro- and nanoelectronic devices. All evaluated components contribute to the final module grade.

Grading scheme*

The overall grade is then determined according to the following scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Teaching and learning methods*

The module combines guided self-study with interactive in-person sessions and hands-on experimental work. Students begin by independently studying selected topics using lecture materials and practical examples provided via Moodle. These are followed by group discussions aimed at deepening understanding, fostering creative thinking, and applying knowledge in small project-based tasks. In addition, students will either conduct experiments themselves or evaluate provided experimental data to gain insights into scientific methods and research-oriented problem solving. Each learning unit concludes with a self-assessment test in Moodle, helping students identify areas for improvement. Additional materials, such as short articles and scientific papers, are available in Moodle for those who wish to explore specific topics in greater depth.

Learning material and required equipment

Lecture notes and supporting materials will be provided via Moodle.

For participation in in-person sessions, experiments, and data evaluation, students are required to bring a laptop or tablet with internet access.

Literature*

Relevant literature, including scientific papers, short scientific articles, and references to key publications, will be provided via Moodle and included in the lecture slides as supporting material.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Fundamental key knowledge, skills and competences for engineers in mathematics, physics and chemistry. Solid basics of materials and solid state physics (materials science of metals, ceramics and semiconductors). Basic knowledge and skills in digital sciences and statistics and in the field of electrical engineering and electronics is an advantage.

Remarks*

n/a

Profile Module
Metals in Applications

Module block: Elective Modules

Module Details		Module Number*	420.xxx
Organization*	Chair of Physical Metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Ronald SCHNITZER		
Deputy Head of Module	Dr.mont. Bak.fk. Oleksandr GLUSHKO		
Contributor*	Priv.-Doz. Dipl.-Ing. Dr.mont. Harald LEITNER, Dipl.-Ing. Dr.techn. Christine ARTNER-WALLNER, Dipl.-Ing. Dr.techn. Paul BARBIC, Dipl.-Ing. Gerald-Karl HEBENSTREIT, Univ.-Prof. Dipl.-Ing. Dr.mont. Stefan POGATSCHER, Dipl.-Ing. Dr.mont. Andreas PICHLER		
Abstract	This module is dedicated to metallic alloys in their application. The production and properties of modern tool steels and steels for the automotive industry are shown. The processing and application of light metal alloys and rare earths metals that are critical raw materials are also covered.		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☒ WS	☐ SS	
Module type*	☒ MI (cont. evaluation)	☐ MN (single examination)	
Contact hours*	5		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	of which attendance is mandatory	20%

Module Details	Module Number*	420.xxx

Module Description

This module is dedicated to metallic alloys in their application. The module consists of four parts. The first one covers the production and properties of modern tool steels and the second one steels for the automotive industry. The third part deals with processing and application of light metal alloys and the fourth part handles rare earths metals.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

Upon successful completion of the module, students will be able to:

(i) develop new tool steels,

(ii) select rare earths metals for various applications with advanced knowledge,

(iii) create concepts for material selection in the automotive industry,

(iv) assess the applicability of alloys for specific requirements..

Contents*

The course will cover

(i) rare earth metals

(ii) tool steels

(ii) processing and application of non-ferrous alloys

(iv) steels for automotive applications

Evaluation - Examination*

Successful completion of the module requires a minimum attendance of 80% and a positive assessment on the tests of each part mentioned above.

In sum a minimum of 50% of the maximum achievable points of all test is necessary to pass the module.

There is also the option to do the module non-immanent, that means without the requirement to fulfil the minimum attendance. The assessment is then done with one single examination on all parts together. That is the unsupported track and has to be requested when registrating for the course at the beginning.

Module Details	Module Number*	420.xxx

Grading scheme*

After fulfilling the requirement of minimum attendance the overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0%:	Very good (1)
75.0% ≤ P < 87.5%:	Good (2)
62.5% ≤ P < 75.0%:	Satisfactory (3)
50.0% ≤ P < 62.5%:	Sufficient (4)
0.0% ≤ P < 50.0%:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Comprehensive knowledge and skills for Bachelor engineers (mathematics, physics, chemistry, technical mechanics, thermodynamics, metallic materials technology).

Remarks*

n/a

Profile Module
Meso-scale Materials Modelling

Module block: Elective Modules

Module Details		Module Number*	420.xxx
Organization*	Chair of physical metallurgy		
Organization ID	420		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.techn. Lorenz ROMANER		
Deputy Head of Module	Univ.-Prof. Dipl.-Ing. Dr.techn. Martin STOCKINGER		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.techn. Lorenz ROMANER; Univ.-Prof. Dipl.-Ing. Dr.techn. Martin STOCKINGER; Dr. techn. Ogris Daniel MARIAN		
Abstract	This module is dedicated to teaching the basic knowledge and methods required for the analysis and design of materials with mesoscopic materials simulation techniques. The module consists of lectures, labs and homework and provides the theoretical foundations of materials simulation software and their application to develop new materials.		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☒ WS	☐ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	5		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	70		
Hours of face-to-face or online teaching	55	**of which attendance is mandatory**	50%

Module Details	Module Number*	420.xxx

Module Description

Content: The course will cover:

- Fundamentals of thermodynamics
- The CALPHAD (Calculation of Phase Diagrams) method.
- Kinetic modeling of materials.
- Diffusion in solids: Fick’s law, mechanisms and role in phase transformations.
- Phase transformation kinetics, nucleation, growth, and coarsening.
- The Avrami equation (Johnson-Mehl-Avrami-Kolmogorov, JMAK model) for modeling isothermal phase transformations.
- Models of dislocation density evolution such as the Kocks-Mecking model.
- Modeling of precipitation, grain growth or recrystallization.
- Material simulation software, Thermocalc, Dictra, Matcalc, JmatPro.
- Phase field method (PFM) for modeling grain growth.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After positive completion of the module, students will be able to:

- explain the basic concepts of thermodynamics and kinetics relevant to the microstructure calculation of materials,
- perform thermodynamic calculations of phase diagrams and prediction of phase stability using CALPHAD-based methods,
- use kinetic modeling techniques to simulate phase transformations, diffusion, microstructure evolution, evolution of dislocation densities and strength,
- use industry standard software tools such as Thermo-Calc, MatCalc and JMatPro,
- use phase field methods to simulate microstructure development.
- Carry out a project on material simulation and design.

Contents*

This module provides basic knowledge and practical skills for calculating the microstructure and properties of materials using common simulation software based on thermodynamic, kinetic and mechanical models aiding the analysis and optimization of materials.

Module Details	Module Number*	420.xxx

Evaluation - Examination*

Successful completion of the module requires a minimum attendance of 50% of all face-to-face units. Furthermore, the following tasks will be graded:

(i) two assessments in form of a 25 min written exams.

(ii) home-work, that students submit on the Moodle platform.

(iii) An own project on a specific topic of mesoscale materials modelling.

All three parts need to achieve a minimum of 50% of the maximum achievable points.

Grading scheme*

After fulfilling the requirement of minimum attendance and after positive completion of all three parts (i) (ii) and (iii), the achieved total percentage is calculated as a weighted average of the percentages p1 and p2 obtained for part (i) and part (ii), respectively.

$P = 0.35*p1 + 0.30*p2 + 0.35*p3$

The overall grade is then determined according to the following grading scheme:

$87.5\% \leq P \leq 100.0\%$:	Very good (1)
$75.0\% \leq P < 87.5\%$:	Good (2)
$62.5\% \leq P < 75.0\%$:	Satisfactory (3)
$50.0\% \leq P < 62.5\%$:	Sufficient (4)
$0.0\% \leq P < 50.0\%$:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundations are taught in classical lecture style using a projector and a chalkboard.

In the lab part the theoretical knowledge is fostered and applied to simple example problems with suitable materials calculation software. The practical skills are strengthened with homework assignments. An own project on mesoscale modelling will also be carried out.

Learning material and required equipment

Lecture notes are provided on moodle. A laptop/tablet is a must for completing the module.

Literature*

Saunders, N., Miodownik, A. (1998). CALPHAD (Calculation of Phase Diagrams): A Comprehensive Guide. United Kingdom: Elsevier Science.

Porter, D.A., Easterling, K.E., & Easterling, K.E. (2009). Phase Transformations in Metals and Alloys (Revised Reprint) (3rd ed.). CRC Press. https://doi.org/10.1201/9781439883570

Prerequisite courses / modules for registration

None

Expected previous knowledge*

Basic knowledge of thermodynamics and statistical physics. Basic concepts of physical metallurgy. Basic knowledge of crystal phases and their defects.

Remarks*

n/a

Profile Module
Continuum Materials Modelling

Module block: Elective Modules

Module Details		Module Number*	400.123
Organization*	Chair of Mechanics		
Organization ID	400		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Thomas ANTRETTER		
Deputy Head of Module	Ao.Univ.-Prof. Mag.rer.nat. Dr.mont. Peter SUPANCIC		
Contributor*	Dipl.-Ing. Dr.mont. Manuel SCHEMMEL, Dipl.-Ing. Wolfgang FLACHBERGER, Dr.mont. MSc Swaroop GADDIKERE NAGARAJA		
Abstract	This module introduces the theoretical concepts for describing material behaviour across length scales from the level of individual grains to the component level. The tools used for modelling range from analytical methods to numerical methods based on the finite element method. Furthermore, it demonstrates how the functionality of established programme code can be extended and customized using user-defined subroutines.		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☒ WS	☐ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	4		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	80%

Module Details	Module Number*	400.123

Module Description

The module consists of a theoretical part, which is taught as a frontal lecture with attendance not mandated but recommended, as well as a tutorial on the practical use of a finite element program applied to relevant engineering problems, where a minimum attendance of 80% is mandatory. The problems are designed in such a way as to demonstrate the immediate relevance of the theory imparted in the frontal lectures. A particular focus is laid on the development of material models and their implementation into a finite element program. To this end the frontal lecture also imparts basic principles of thermodynamics and mechanics of continua.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successful completion of the course the students will be able to

- derive the fundamental equation of the finite element method (FEM),
- formulate polynomial shape functions for continuum elements,
- assemble element stiffness matrix and element load vector,
- assemble global stiffness matrix and global load vector
- incorporate boundary conditions into the fundamental equation of the FEM and formulate the final system of algebraic equations
- choose a time-integration method suitable for time dependent problems
- set up an APDL Script for the finite element program ANSYS
- numerically solve simple engineering problems with ANSYS
- formulate (visco)elastic material laws using constitutive equations and internal variables
- formulate rate-independent and -dependent plasticity, linear and kinematic hardening laws
- derive algorithmically consistent stress and tangent modulus tensor
- implement the constitutive equations into a finite element program

Contents*

Numerical methods: Vector and tensor calculus, outline of a linear static finite element analysis, finite functions, finite elements, polynomial shape functions, virtual work principle, fundamental equation of the finite element method, element stiffness matrix, element load vector, coincidence table, global stiffness matrix, global load vector, Dirichlet vs. Neumann boundary conditions, normalized local coordinate frames, parametric elements, numerical integration, direct and indirect time integration schemes. Practical work with the finite element program ANSYS and the scripting Language APDL for selected example problems.

Material models: Physical balance principles and the idea of thermodynamic consistency, basic material laws--elastic and viscoelastic--using constitutive equations and the concept of internal variables, rate- independent and rate-dependent plasticity, linear and kinematic hardening laws, associated and non-associated flow rules in plasticity, algorithmically consistent stress and tangent modulus tensor, solution concepts for non-linear equations using iterative methods, implementation of the constitutive equations into a finite element program.

Module Details	Module Number*	400.123

Evaluation - Examination*

Successful completion of the module requires a minimum attendance of the tutorials of 80% of all tutorial units, as well as a positive assessment of two parts: (i) a theory test for evaluating the knowledge on the theoretical background, (ii) an assessment of the student's proficiency in using the finite element program ANSYS.

Part (i) consists of two tasks: a theory quiz as well as an example of a simple problem of continuum physics to be translated into a numerically accessible format. Both tasks have to be completed using the test activity of the learning management system Moodle, where the duration of the first task is 70min, and of the second part 100min.

Part (ii) requires the completion of homework assignments, i.e. simple engineering problems to be solved using the commercial finite element program ANSYS. The solutions will then be presented and discussed with the tutor. Based on the student's ability to defend his/her solution the tutor will evaluate the student's performance.

Both parts (i) and (ii) have to achieve a minimum of 50% of the maximum achievable points.

Grading scheme*

After fulfilling the requirement of minimum attendance and after positive completion of both part (i) and (ii), the achieved total percentage is calculated as a weighted average of the percentages p1 and p2 obtained for part (i) and part (ii), respectively.

P = 0.6*p1 + 0.4*p2

The overall grade is then determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0%:	Very good (1)
75.0% ≤ P < 87.5%:	Good (2)
62.5% ≤ P < 75.0%:	Satisfactory (3)
50.0% ≤ P < 62.5%:	Sufficient (4)
0.0% ≤ P < 50.0%:	Not sufficient (5)

Teaching and learning methods*

The theoretical foundation is taught in classical lecture style using a projector and a chalkboard. In particular, the lecture shows how to translate a physical phenomenon mathematically described a boundary value problem into a numerical solution scheme.

In the tutorials the theoretical knowledge is fostered and applied to simple example problems using a commercial finite element program under the guidance of a tutor. The practical skills in using a finite element program are then strengthened with homework assignments.

Module Details	Module Number*	400.123

Learning material and required equipment

Lecture notes are provided. Additionally, for the theory part the transparencies for the presentation are available on Moodle.

There is no special equipment need for the theory lectures. For the tutorials PCs will be provided in a designated computer lab. For working on the homework assignments a PC or a laptop computer is needed. A student license for ANSYS will be provided.

The theory exam will take place in the computer lab. It is necessary to bring a student ID as well as a certified calculator, i.e. a calculator that has been approved for use in exams.

Literature*

Thomas J.R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Pubn Inc 2000,

Jacques Besson , Georges Cailletaud , Jean-Louis Chaboche , Samuel Forest, Non-Linear Mechanics of Materials, Springer Science+Business Media B.V. 2010

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Comprehensive knowledge of vector and tensor calculus as well as mechanics of materials.

Remarks*

n/a

Profile Module
Correlative Materials Analysis

Module block: Elective modules

Module Details		Module Number*	430.XXX
Organization*	Chair of Materials Physics		
Organization ID	430		
Module Manager	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER		
Deputy Head of Module	Dipl.-Ing. Dr.mont. Michael TKADLETZ		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.mont. Daniel KIENER, Dipl.-Ing. Dr.mont. Markus ALFREIDER, Dipl.-Ing. Dr.mont. Anton HOHENWARTER, Priv.-Doz. Dr. Zaoli ZHANG, Univ.-Prof. assoz.Prof. Dr. Jozef KECKES, Mag. et Dr.rer.nat. Florian SPIECKERMANN, Ass.-Prof. DDipl.-Ing. Dr.mont. Sabine BODNER		
Abstract	This module addresses various correlative methods and the necessary preparation and analysis techniques for the evaluation and interpretation of the global and local deformation behaviour and the structural and chemical state of materials.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒	WS	☐	SS
Module type*	☒	**MI** (cont. evaluation)	☐	**MN** (single examination)
Contact hours*	3			
ECTS credits*	5			
Participation quota*	☒	no	☐	yes

Expected Workload			
Total hours	125		
Hours of self-study	90		
Hours of face-to-face or online teaching	35	**of which attendance is mandatory**	80%

Module Details	Module Number*	430.XXX

Module Description

The module consists of the following parts:

Part 1: Imaging based deformation analysis

In this first part, imaging based methods suited for correlative material analysis will be covered. This involves local deformation measurements using methods such as digital image correlation, as well as strain determination using approaches building upon as electron diffraction or electron backscatter diffraction.

Part 2: Synchrotron based analysis

The second part will provide the foundations of synchrotron based experiments and diffraction analysis, to subsequently evaluate local stress- and strain distribution using methods such as static and in-situ micro-/nanobeam diffraction.

Both parts will focus on a scale bridging material analysis combining different material responses, as well as linking observations from different length scale (atomic, micro, meso), to derive a comprehensive rational of the resultant bulk material behaviour.

Part 3: Data analysis

Building upon the theoretical knowledge acquired in the previous parts, the students will be provided with datasets from specific correlative experiments and have to analyse the data to compile and submit a report.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully passing the module, students have acquired the following knowledge, skills and competences:

• Assess the application of synchrotron methods for material science problems

• Differentiate approaches to address transient material states and argue their benefits and limitations

• Interpret scale bridging mechanical material analysis approaches

• Utilize digital image correlation and strain mapping approaches to measure local strain and interpret the outcomes

• Interpret correlations between local chemical and structural information and bulk material characteristics

• Analyse selected correlative data sets by open source software and interpret the outcomes.

Module Details	Module Number*	430.XXX

Contents*

Content: This module addresses correlative methods and necessary preparation and analysis techniques for assessing and interpreting the global and local material phase composition, deformation state, as well as the structural and chemical state. The course covers:

• Synchrotron based methods for structural and transient material characterization

• Connecting global to local deformation state in heterogeneous microstructures

• Digital image correlation for local deformation analysis

• 4D STEM methods and analysis routines for nanoscale materials analysis

• Linking local and global structural and chemical information with respective mechanical properties

• Manage open software packages for correlative material analysis (mtex, GOM correlate, py4DSTEM)

• Students assess a provided dataset (Synchrotron diffraction, EBSD, DIC, 4D STEM) and interpret the outcomes

Evaluation - Examination*

Successful completion of the module requires a positive assessment on continuous tests after the different module parts. Part 3 requires a positive evaluation of the report.

Grading scheme*

After positive completion of part 1-3 the total percentage is calculated as a weighted average of the percentages of Part 1-3, respectively.

P = 0.4*Part 1 + 0.4*Part 2 + 0.2*Part 3

The overall grade is determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Module Details	Module Number*	430.XXX

Teaching and learning methods*

The teaching format for parts 1 and 2 is primarily a frontal lecture, supported by a Moodle course and demonstrations performed in the laboratory. Part 3 involves problem-based learning, where a defined data set on a selected materials science problem with emphasis on the used techniques is analysed by the participants and described in a written report.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Significant literature will be announced in the first lecture of each part.

Prerequisite courses / modules for registration

Demonstrate comprehensive knowledge of materials, microstructures, and infer their influence on mechanical properties. Express fundamental understanding of material characterization methods.

Expected previous knowledge*

Demonstrate comprehensive knowledge of materials, microstructures, and infer their influence on mechanical properties. Express fundamental understanding of material characterization methods.

Remarks*

n/a

Profile Module
Additive Manufacturing

Module block: Elective Modules

Module Details		Module Number*	410.xxx
Organization*	Chair of Structural and Functional Ceramics		
Organization ID	410		
Module Manager	Ao.Univ.-Prof. Dipl.-Ing. Dr. mont. Tanja LUBE		
Deputy Head of Module	Univ.-Prof. Dipl.-Ing. Dr.-Ing.habil. Dr.h.c. Jürgen ECKERT		
Contributor*	Univ.-Prof. Dipl.-Ing. Dr.-Ing.habil. Dr.h.c. Jürgen ECKERT, Ao.Univ.-Prof. Dipl.-Ing. Dr. mont. Tanja LUBE, Ass.Prof. Dipl.-Ing. Dipl.-Ing. Dr.mont. Sabnie BODNER, Priv.-Doz. HR Dipl.-Ing. Dr.mont. Christian KUKLA, Dipl.-Ing. Dr.mont. Gerald RESSEL		
Abstract	This module teaches the basic principles of additive manufacturing. Various processes are explained and assessed in terms of their applicability for the various material classes. Selected processes for metals and ceramics are taught in detail with regard to process parameters, requirements for component design, material selection, properties and their characterization. Novel component and material concepts are discussed.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒ WS	☐ SS		
Module type*	☐ **MI** (cont. evaluation)	☒ **MN** (single examination)		
Contact hours*	4			
ECTS credits*	5			
Participation quota*	☒ no	☐ yes		

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	0%

Module Details	Module Number*	410.xxx

Module Description

The module consists of the following parts:

Part one deals with basic principles and technologies of AM, part two concentrates on aspects of AM with metallic materials, part three focuses on AM with ceramics.

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successfully completing the module, students will be able to:

(i) assess the additive manufacturing (AM) of metals and ceramics according to aspects of materials science aspects,

(ii) critically evaluate the choice of specific AM processes and materials for selected components and justify them,

(iii) assess the performance of AM-manufactured components on the basis of process- and material-related material-related characteristics,

(iv) design and carry out complex research and development tasks in the field of AM and and develop new strategic approaches,

(v) set up economic process chains with the help of additive manufacturing.

Contents*

The following topics are addressed:

Motivation for AM, economic aspects, market analysis

Basic principles of AM (CAD, slicing, data management, ...), classification of AM methods, process descriptions, applicability for different material classes, size scales

Metal AM: relevant processes (powder bed fusion, powder bed sintering, electron beam melting, direct energy deposition), process variables, powder fabrication and characteristics, relation between process parameters, microstructures and properties, typical defects, characterization techniques, residual stresses, properties of resulting materials (steels, Ni-, Al-, Ti-based alloys), material design for AM, component design, topology optimization, (potential) applications, reverse engineering.

Ceramic AM: relevant processes (vat-photopolymerisation, material extrusion, material jetting, binder jetting), process variables, feedstock fabrication, properties and characterization: binder systems and photopolymers, relation between process parameters, microstructures and properties, thermal treatment strategies, typical defects, characterization techniques, material properties, material design.

Cross-cutting topics: design, manufacturing and mechanical behavior of cellular structures and composites, metamaterials, in-line process control.

Module Details	Module Number*	410.xxx

Evaluation - Examination*

The assessment takes the form of a 120-minute written exam. The examination covers the three above mentioned parts. In sum a minimum of 50% of the maximum achievable points is necessary to pass the exam

Grading scheme*

The overall grade is then determined according to the following scheme

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)]

Teaching and learning methods*

The contents are taught in classical lecture style using a projector and a chalkboard.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle

Literature*

Will be announced in the course.

Prerequisite courses / modules for registration

n/a

Expected previous knowledge*

Bachelor-level knowledge, skills and competencies in the areas of processing of metals, ceramics and polymers, structure-property relationships of materials and mechanical behavior of materials.

Remarks*

n/a

Profile Module
Advanced Materials Testing

Module block: Elective Modules

Module Details		**Module Number***	**425.xxx**
Organization*	Chair of Functional Materials and Materials Systems		
Organization ID	425		
Module Manager	Ass.Prof. Dr.-Ing. Verena MAIER-KIENER		
Deputy Head of Module	Dipl.-Ing. Dr.mont. Anton HOHENWARTER		
Contributor*	Ass.Prof. Dr.-Ing. Verena MAIER-KIENER, Univ.-Prof. Dipl.-Ing. Daniel KIENER, Dipl.-Ing. Dr.mont. Anton HOHENWARTER, Dipl.-Ing. Dr. mont. Markus ALFREIDER, Dipl.-Ing. Dr. mont Anna JELINEK, Prof. Dr. mont. Peter HOSEMANN (UC Berkeley), Prof. Dr.-Ing. Benoit MERLE (Uni Kassel),		
Abstract	The content of this profile module deals with modern material testing methods, with a focus on the characterization of mechanical properties. Particular attention is paid to small-scale testing methods and investigations under operando conditions, such as under the influence of temperature or in electrochemical environments.		

General Data				
Module level	Master			
Language*	English			
Recommended semester*	☒	WS	☐	SS
Module type*	☒	**MI** (cont. evaluation)	☐	**MN** (single examination)
Contact hours*	4			
ECTS credits*	5			
Participation quota*	☒	no	☐	yes

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	80%

Module Details	Module Number*	425.xxx

Module Description

The module consists of the following 3 parts – 2 theoretical and 1 practical:

Part 1: Nanomechanical Testing Techniques

Advanced materials testing techniques involve small-scale mechanical methods such as nanoindentation, micro-pillar compression, micro-tension, scratch, and bulge testing to assess material behavior at the micro- and nanoscale. These techniques enable the study of thermally activated deformation mechanisms, including strain-rate sensitivity, creep, and fatigue behavior using advanced protocols like dynamic nanoindentation. Additionally, they allow for the extraction of localized flow curves, providing deeper insights into material performance under complex loading conditions.

Part 2: In-situ and operando conditions during mechanical testing

This part covers experimental techniques performed within SEM or TEM environments, allowing real-time observation of microstructural changes during mechanical loading. These methods offer high spatial resolution and direct correlation between deformation and structural evolution, though they may be limited by sample size, environmental constraints, and electron beam effects. This part also explores mesoscopic and scale-bridging testing strategies that link nano- and micro-mechanical behavior to macroscopic properties. Operando testing under extreme conditions, such as high or cryogenic temperatures, electrochemical charging, and radiation exposure, enables comprehensive evaluation of materials using techniques like nanoindentation, micromechanics, and fracture toughness testing.

Part 3: Applying advanced methods to real materials system

While Parts 1 and 2 mainly deal with theoretical materials testing topics illustrated by application-oriented examples, Part 3 will focus on experimental implementation within ***several practical units***. These units will include in-situ investigations in the SEM, cross-scale operando testing, and advanced testing methods for determining high-throughput data and thermally activated processes.

Moodle support*

☒ Yes	☐ No

Course Work / Evaluation

Learning outcomes*

(i) Well-founded, highly specialized knowledge in the field of modern materials testing, which forms the basis for innovative thinking and the development of new research approaches relevant to materials testing under laboratory and application-oriented conditions,

(ii) Strong critical awareness of key issues in the field of advanced materials testing, including the evaluation of future potentials and the analysis of current limitations of applicability (especially under operando conditions, such as temperatures or electrochemical environments).

(iii) Highly developed problem-solving skills, which are required in research in the field of modern materials testing and form the basis for the acquisition of new scientific knowledge, the correlation between material properties (mechanical, functional) and material structure as well as the development of future material innovations.

Module Details	Module Number*	425.xxx

Contents*

Within this module, the fundamental key knowledge, skills and competences necessary for research and application of advanced materials testing will be communicated and trained within lectures, a practical part as well as some seminar.

The module covers the following topics:

- Advanced materials testing techniques
  - Micromechanics: nanoindentation, micro-pillar compression and micro-tension testing, scratch and bulge testing
  - Advanced testing protocols for small scale mechanical testing to gain knowledge on thermally activated deformation behavior (e.g. strain-rate sensitivity, creep behavior), fatigue behavior (dynamic indentation) and localized flow curves
  - In-situ experiments performed with in the SEM or TEM – advantages and challenges of electron imaging during testing
  - Mesoscopic and scale bridging testing approaches
- Scale bridging operando testing:
  - High and cryogenic temperatures, electro-chemical charging, nuclear environments, photoelectric as well as electrical contact resistance, etc
  - Nanoindentation, micromechanics, mesoscopic fracture toughness
- Degree of fidelity:
  - Application of small scale testing techniques to industry relevant topics,
  - Application in high-throughput testing and as screening methodologies.
  - Problem-based learning
- Development and training of competences by solving defined problems related to advanced materials testing based on the existing background of scientific literature
- Presentation of developed problem-solving strategies and defense of the presented solutions

Evaluation - Examination*

Successful completion of the module requires a positive assessment on continuous tests after the different module parts 1- and 2. Part 3 requires a positive evaluation of the report.

Grading scheme*

After positive completion of part 1-3 the total percentage is calculated as a weighted average of the percentages of Part 1-3, respectively.

P = 0.4*Part 1 + 0.4*Part 2 + 0.2*Part 3

The overall grade is determined according to the following grading scheme:

87.5% ≤ P ≤ 100.0% : Very good (1)

75.0% ≤ P < 87.5% : Good (2)

62.5% ≤ P < 75.0% : Satisfactory (3)

50.0% ≤ P < 62.5% : Sufficient (4)

0.0% ≤ P < 50.0% : Not sufficient (5)

Module Details	Module Number*	425.xxx

Teaching and learning methods*

The teaching format for parts 1 and 2 is primarily a frontal lecture (including guest lectures by experts from Germany and USA), supported by a Moodle course and demonstrations performed in the laboratory. Part 3 involves problem-based learning, where a defined data set on a selected materials science problem with emphasis on the used techniques is analysed by the participants and described in a written report.

Learning material and required equipment

Lecture notes are provided and will be made available on Moodle.

Literature*

Significant literature will be announced in the first lecture of each part.

Prerequisite courses / modules for registration

Bachelor-degree in a Materials Science related field

Expected previous knowledge*

Fundamental key knowledge, skills and competencies for engineers at Bachelor level (mathematics, physics, chemistry, technical mechanics);

Fundamentals of materials technology, materials characterization and general materials properties and in particular mechanical testing techniques of metals, ceramics and semiconductors.

Remarks*

n/a

Profile Module
Biomaterials and Soft Matter

Module block: Elective Modules

Module Details		Module Number*	460.201
Organization*	Chair of Physics		
Organization ID	460		
Module Manager	Univ.-Prof. Dr. Oskar PARIS		
Deputy Head of Module	Dr. Florian SPICKERMANN		
Contributor*	Univ.-Prof. Dr. Oskar PARIS, Dr. Gerhard POPOVSKI, Dr. Florian SPIECKERMANN		
Abstract	This module deals with the structure and the mechanical and functional properties of soft matter and biological materials. It focuses on the physical/chemical understanding of self-organization processes, the hierarchical structure of biological composite systems and biomimetic material concepts		

General Data			
Module level	Master		
Language*	English		
Recommended semester*	☒ WS	☐ SS	
Module type*	☒ **MI** (cont. evaluation)	☐ **MN** (single examination)	
Contact hours*	4		
ECTS credits*	5		
Participation quota*	☒ no	☐ yes	

Expected Workload			
Total hours	125		
Hours of self-study	80		
Hours of face-to-face or online teaching	45	**of which attendance is mandatory**	30%

Module Details	Module Number*	460.201

Module Description

The course consists of 4 SWS, equivalent to 45 full hours or 22.5 course units, with one unit comprising two full hours

- **Lecture part:** 15 units (attendance recommended but not compulsory)
- **Intermediate quiz** (multiple choice type): 0.5 units, attendance compulsory
- **Seminar part** with student presentations: 6 units, attendance compulsory for 4/6 units
- **Final exam** (oral): 1 unit, attendance compulsory

Students are given the choice of an unsupervised track. These students will have access to the course material on Moodle and are allowed to attend the lectures, but not the seminar part. Their final exam will consist of an extended written exam (2 hours) followed by an oral exam (1 hour).

Moodle support*

☒ yes	☐ no

Course Work / Evaluation

Learning outcomes*

After successful completion of the module, students will be able to:

(i) describe and explain the basic physico-chemical properties of colloid systems and soft matter and in particular their self-organization,

(ii) name and describe important biopolymers (proteins, polysaccharides, lipids) and their relevance for materials science,

(iii) describe the composition and (hierarchical) structure of important biological materials (e.g. bone, wood, mother-of-pearl),

(iv) understand mechanical and functional properties of biological materials in the context of their hierarchical structure,

(v) abstract structural principles of biological materials for the development and production of new functional (bio-inspired) materials.

Contents*

Lecture content

biological-, bioinspired-, bioderived- and bio(medical) materials; colloidal interactions; colloidal systems; synthesis and characterization of colloidal systems; mechanical concepts in nature; biopolymers; soft tissues; plants and arthropod cuticles; wood; biomineralization; bone; biomedical materials.

Seminar content
Students will prepare presentations on selected actual topics within the scope of the module but not previously covered in the lecture part; literature search, presentation and discussion in the group.

Module Details	Module Number*	460.201

Evaluation - Examination*

Supervised track (max 100 points, minimum 50 points)

- **Seminar part** (max 35 points): 20-30 min presentation of a specific topic (max 20 points) followed by answering questions from supervisors and colleagues (max 10 points). The remaining 5 points can be gathered from further active contributions (asking questions!) after presentations of colleagues. Attendance is compulsory for at least 4/6 seminar units. The seminar part counts 35% for the final mark.
- **Intermediate quiz** (max 25 points, min 10 points): written exam in the form of a multiple-choice test, attendance is compulsory; counts 25% for the final mark
- **Final exam** (max 40 points, min 15 points): oral exam, attendance is compulsory; counts 40% for the final mark (max 40 points). In case of failure, the final exam can be repeated once within the next Semester following the Module

Unsupervised track (max 100 points, minimum 50 points)

Single exam consisting of a **written part** (max 50 points, minimum 15 points) with multiple-choice test and specific knowledge questions including calculus problems, followed by an **oral part** (max 50 points, minimum 15 points). Negative exams for the unsupported track can be repeated at maximum four times. Exam dates should will be arranged upon request (minimum 3 dates each semester if requested).

Grading scheme*

The maximum number of points to be reached for both, the supervised and the unsupervised track is 100. The final grade will be calculated according to the following scheme

$87.5 \leq P \leq 100.0\%$: Very good (1)

$75.0 \leq P < 87.5\%$: Good (2)

$62.5 \leq P < 75.0\%$: Satisfactory (3)

$50.0 \leq P < 62.5\%$: Sufficient (4)

$0.0 \leq P < 50.0\%$: Not sufficient (5)

Teaching and learning methods*

Frontal lecture (ca 70%), Seminar (ca 30%)

Learning material and required equipment

Lecture notes are provided on Moodle

Literature*

Provided on Moodle

Prerequisite courses / modules for registration

No formal pre-requisite

Expected previous knowledge*

Basic knowledge of physics, physical chemistry and materials science at Bachelor level is a must. Some pre-knowledge on structural and functional materials as well as solid-state physics, thermodynamics and mechanical testing are expected.

Remarks*

n/a