Faculty of Biology, Chemistry, and Geoscience

Master Program

Materials Chemistry and Catalysis

Module Handbook

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Content

Materials science is an interdisciplinary field within the classical subjects of chemistry, physics, mineralogy, and engineering. Materials science represent one of the most important and challenging cross-sectional disciplines within natural sciences. Materials scientists are needed in many areas of industry, e.g., to develop modern high-performance materials or new functional materials. The development of new materials has contributed decisively to the technical progress of the last decades in a multitude of areas. Growth and prosperity in the 21st century will also be driven to a large extent by innovations and new developments in materials synthesis. Substantial improvements or new material properties are prerequisite for tomorrow’s product development, on which in turn a society based on high technology such as Germany is dependent. The motor for the necessary developments is fueled by new material concepts such as nanomaterials, inorganic-organic hybrid materials, composites, colloidal molecules, materials in non-equilibrium states, surface-active materials, or biomimetic materials. Progress in polymeric materials is also driven decisively by new catalysts that enable the targeted variation of material properties. The basis for the development of improved materials is a solid understanding of the relationships between composition, structure and morphology of the materials and their chemical and physical properties.

Addressing the challenges and requirements in materials science is of enormous economic and technical importance in a wide variety of sectors; materials chemistry makes decisive contributions to this. Accordingly, the demand for relevantly trained graduates is very high and continues to increase. Graduates of this degree program have access to a wide range of fields of activity in the most diverse economic and scientific areas. The career prospects are therefore excellent, and graduates have access to diverse and varied fields of work: Nano and mesotechnology, lightweight construction, microelectronics and semiconductor technology, sensor technology, many aspects of energy supply such as water management, batteries, accumulators and fuel cells for mobile electronic devices and vehicles as well as the further development of solar technology and hydrogen economy, which is becoming increasingly important in the context of climate change, are just a few examples.

The study program *“Materials Chemistry and Catalysis”* teaches the chemical and physical fundamentals of all important material classes, from organic polymers and hybrid materials to ceramic materials and metals. The degree program intentionally focuses on the chemical aspects of the cross-sectional science of materials science in order to train graduates with a clearly visible qualification profile and with a chemical core competence. Equal attention is paid to basic and application aspects, preparation, and comprehensive characterization with a range of complementary methods. Graduates of the program are enabled by their chemical competence to synthesize, modify and characterize materials for varying demands, as well as to assess their potential applications allowing to solve materials science problems together with other materials scientists.

The two-year Master's program "Materials Chemistry and Catalysis" is aimed at students with a Bachelor's degree in chemistry, polymer and colloid chemistry, biochemistry, teaching with a corresponding subject combination, and related disciplines. The Master's program "Materials Chemistry and Catalysis" can be started either in the winter or summer semester. In the first year of study, students take seven modules from a selection of fourteen, typically consisting of lectures and laboratory courses that familiarize the subject by experiments and to train their practical skills. In the first semester, students choose four out of seven proposed modules (e.g. for the start in the winter semester: Solid-state Inorganic Materials: Nanochemistry, Homogeneous Catalysis, Electrochemical Energy Systems and Energy Conversion, Colloids and Surfaces, Stereoselective Organic Synthesis, Polymer Synthesis, Biomaterials), but at least one from each of the core areas "Inorganic Chemistry", "Colloids and Materials" and "Organic Chemistry and Macromolecular Materials" in order to assure the appropriate breadth of the acquired knowledge. The fourth module can also be selected from the other courses offered in this degree program or other Master's degree programs in chemistry.

In the second semester, students take three in-depth modules, each worth nine credit points. These modules each include a longer internship in one of the research groups involved in the study program. Possible modules for winter starters are: Solid-state Inorganic Materials: Properties and Applications; Catalyst Design, High Performance Materials for Electrochemical Energy Systems, Advanced Methods in the Physical Chemistry of Polymers, Materials for Sensors, Catalysis and Energy Conversion, From Macromolecule to Material, Applied Functional Polymers. In addition, the students prepare the planning for their own scientific research project by writing a research proposal.

In the third and fourth semesters, two “Advanced Laboratory” courses totaling 30 credit points are to be completed at the student's discretion, whereby one of these can also be carried out as part of an industrial placement and/or abroad. The topic of the master's thesis on current issues in materials chemistry and catalysis can already be handed out at the end of the second semester, so that the preparation for the independent scientific work can take place in parallel with the advanced laboratory modules. The master's thesis with a total of 30 credit points is carried out over a period of 6 months in the fourth semester.

A total of at least 120 credit points must be earned in the Master's program "Materials Chemistry and Catalysis" (1^{st} semester: 28; 2^{nd} semester: 32; 3^{rd} plus 4^{th} semester: 60). An overview of the courses offered in the Master's program is given in the following scheme. The contents and details of the individual modules are explained in the remaining part of this module handbook.

Coordinator of the *Master Program*

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Modular structure, teaching areas, teaching load (lectures: V, laboratory (P) given in hours per week HPW), and credit points (CP) of the Master's program "Materials Chemistry and Catalysis".

1. Semester when beginning in winter* (28 CP)

winter modules C101 – C107 Select 4 out of 7 modules * with 7 HPW of laboratory	Modul C101	Modul C102	Modul C103	Modul C104
	Solid-state Inorganic Materials: Nanochemistry	**Homogeneous Catalysis**	**Electrochemical Energy Systems and Energy Conversion**	**Colloids and Surfaces**
	7/9 CP	7/9 CP	7/9 CP	7 CP
	V 2 HPW P 6/8 HPW	V 2 HPW P 6/8 HPW	V 2 HPW P 6/8 HPW	V 2 HPW P 6 HPW
	Modul C105	Modul C106	Modul C107	
	Stereoselective Organic Synthesis	**Polymer Synthesis**	**Biomaterials**	
	7 CP	7 CP	7/9 CP	
	V 2 HPW P 6 HPW	V 2 HPW P 6 HPW	V 2 HPW P 6/8 HPW	

*The master course may be started both in the winter or summer semester. Winter beginners choose four modules of 7 CP each in the first semester, but at least one module each from the areas "Inorganic Chemistry" (C101-C102), "Colloids and Materials" (C103-C104) and "Organic Chemistry and Macromolecular Materials" (C105-C107). One module can be taken from the other courses offered in this degree program or other Master's programs in chemistry. Summer beginners choose three modules with a longer laboratory course of 9 CP each from the selection of winter modules in the second semester. Modules that are only listed with 7 CP cannot be selected in the second semester.
[V = lecture; Ü = exercise; S = seminar; P = laboratory course. HPW = semester hours per week]

2. Semester when beginning in winter* (32 CP)

summer modules C201 – C207 Select 4 out of 7 modules * with 7 HPW of laboratory	Modul C201	Modul C202	Modul C203	Modul C204
	Solid-state Inorganic Materials: Properties and Applications	**Catalyst Design**	**High Performance Materials for Electrochemical Energy Systems**	**Advanced Methods in the Physical Chemistry of Polymers**
	9/7 CP	9/7 CP	9/7 CP	9/7 CP
	V 2 HPW P 8/6 HPW	V 2 HPW P 8/6 HPW	V 2 HPW P 8/6 HPW	V 2 HPW P 8/6 HPW
	Modul C205	Modul C206	Modul C207	
	Materials for Sensors, Catalysis and Energy Conversion	**From Macromolecule to Materia l**	**Applied Functional Polymers**	
	9/7 CP	9/7 CP	9/7 CP	
	V 2 HPW P 8/6 HPW	V 2 HPW P 8/6 HPW	V 2 HPW P 8/6 HPW	

* **Students beginning in the winter semester** choose three modules with a long laboratory course of 9 CP each in the second semester. In addition, the planning of an own research project (research proposal) is carried out within the scope of a fourth module (C210) with a weighting of 5 CP. **Students beginning in the summer semester** choose four modules with a short laboratory course of 7 CP each from the range of summer modules in the first semester, but at least one module each from the areas "Inorganic Chemistry" (C201-C202), "Colloids and Materials" (C204-C205) and "Organic Chemistry and Macromolecular Materials" (C206-C207). One module can be taken from the other courses offered in this degree program or other Master's programs in chemistry. The modules C206 and C207 require C106 and can therefore usually not be chosen for summer beginners.
[V = lecture; Ü = exercise; S = seminar; P = practical course. HPW = semester hours per week

Module	Modul C210 **Research Proposal** 5 CP 9 HPW

3. and 4. Semester (60 LP inklusive Masterarbeit)

Module *	Modul C301 **Advanced Labora-tory I** 15 LP P 19 HPW S 1 HPW	Modul C302 **Advanced Laboratory II** 15 LP P 19 HPW S 1 HPW

* From the selection of modules taken in the first year. One of these modules can be replaced by a laboratory course at a university abroad and/or an industrial internship.

Module	Modul C400 **Master Thesis** 30 CP 900 hours

Module C 101: Solid-State Materials: Inorganic Nanochemistry

Learning objectives:

The main aim of this module is to provide a sound and broad knowledge about current developments of solid inorganic materials with a focus on nanochemistry.

Course units and temporal allocation:

Module C 101, Solid-State Materials: Inorganic Nanochemistry' is comprised of the following course units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by lecturers of Inorganic Solid-State Chemistry

Course content:

During the lecture properties, applications and theoretical considerations of solid inorganic functional materials will be presented. Special care will be given to mechanistic aspects of synthetic routes as well as to modern characterization strategies. The following items will be discussed: i) Inorganic Nanotechnology including the build-up of inorganic colloids, pigments, nano-rods and -wires. ii) Inorganic composite and filling materials including biogenic minerals like nacre and bone tissue. iii) Crystal engineering and polymorphism of molecular systems as well as their influence on drug design. iv) Supramolecular inorganic chemistry and host guest systems. v) Semi-crystalline and amorphous materials including glasses, glass ceramics, phase change materials and photonic crystals.

In the ***laboratory course*** the students will deepen their practical skills by working with experienced PhD students and postdocs in the group of the lecturers.

Entrance requirements:

None

Assessment:

A written or oral examination covering the content of the lecture amounts to 5 CP and the quality of the lab course to 2/4 CP. Lab. course assessment results from the quality of syntheses, characterization, and discussion of results. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Given 15 weeks per semester this leads to 60 hours workload. For the lab course 120/180 hours has to be considered. Together with 30 hours for the preparation of the final examination a total workload of 210/270 hours for the whole semester results.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 102: Homogeneous Catalysis

Learning objectives:

The students gain insight into polymerization catalysis and improve their knowledge in organometallic chemistry.

Course units and temporal allocation:

Module C 102, Homogeneous Catalysis' is comprised of the following course units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by lecturers of Molecular Inorganic Chemistry

Course content:

During the ***lecture*** the following topics are discussed: reactivity of the metal carbon bond, catalytic applications of organometallic compounds and coordinative polymerizations.

In the ***laboratory course*** the students improve skills to work with highly air and moisture sensitive compounds and use them in teamwork with PhD students and postdocs to address catalysis relevant questions.

Entrance requirements:

None

Assessment:

A written or oral examination covering the content of the lecture amounts to 5 CP and the quality of the lab course to 2/4 CP. Lab. course assessment results from the quality of the catalyst syntheses and the quality of the catalytic experiments. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload:

The lecture results in 60 hours workload including lecture preparation and the laboratory course workload is 120 hours. 30 hours are needed to prepare for the examination.
Overall workload: 210 h.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 201: Solid-State Materials: Properties and Application

Learning objectives:

This course intends to present the students with a sound and broad knowledge about important material classes and their applications in the field of solid-state chemistry.

Course units and temporal allocation:

Module C 201, Solid-State Materials: Properties and Application' is comprised of the following course units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by lecturers of Inorganic Solid-State Chemistry.

Course content:

The lecture focuses on important material classes in the field of solid-state chemistry and informs about their applications. Advantages and disadvantages of typical preparation techniques will be discussed including high-temperature or solvothermal syntheses, self-organisation and imprinting. Furthermore, fundamental thermodynamic (phase transitions and meta-stability), kinetic (nucleation and growth) and dynamic (defects and ion conduction) properties of solids will be addressed which influence the synthesis strategies as well as the application potential of the resulting materials. The following items will be covered: i) high-surface materials like micro- and mesoporous compounds for the use of heterogenous catalysis, sensors and gas storage. ii) Hard materials and ceramics. iii) Materials for optical applications. iv) Energy storage and conversion materials like thermoelectrica, supercapacitors, batteries and fuel cells. v) Magnetic properties of metals and metal oxides and magnetic devices.

In the ***laboratory course*** the students will deepen their practical skills by working with experienced PhD students and postdocs in the group of the lecturers.

Entrance requirements:

None

Assessment:

A written or oral examination covering the content of the lecture amounts to 5 CP and the quality of the lab course to 2/4 CP. Lab. Course assessment results from the quality of syntheses, characterization, and discussion of results. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Given 15 weeks per semester this leads to 60 hours workload. For the lab course 120/180 hours has to be considered. Together with 30 hours for the preparation of the final examination a total workload of 210/270 hours for the whole semester results.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C202: Catalyst Design

Learning objectives:

The students gain insight into the field of catalyst design.

Course units and temporal allocation:

Module C 202 ‚Catalyst Design' is comprised of the following course units:

	HPW	Semester
Lecture	2	SS
Laboratory Course	8	SS

This module will be offered by lecturers of Molecular Inorganic Chemistry

Course content:

During the ***lecture*** the following topics are discussed: basics and concepts of catalyst design: explorative coordination chemistry, mechanistic studies, and combinatorial catalysis research.

In the ***laboratory course*** the students develop skills to run catalytic experiments and use them in teamwork with PhD students and post-docs to address open, catalysis relevant, questions.

Entrance requirements:

None

Assessment:

A written or oral examination covering the content of the lecture amounts to 5 CP and the quality of the lab course to 2/4 CP. Lab. course assessment results from the quality of the catalyst syntheses and the quality of the catalytic experiments.

Workload:

The lecture results in 60 hours workload including lecture preparation and the lab course workload is 180 hours. 30 hours are needed to prepare for the examination.
Overall workload: 270 h.

ECTS Credit Points: ***7/9****

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 203: High Performance Materials for Electrochemical Energy Systems

Learning objectives:

Students will be introduced to modern electrochemical energy systems with a focus on rechargeable batteries. The course includes aspects of electrochemistry and cell design with a focus on materials development (synthesis, characterisation and functionalisation).

Course units and temporal allocation:

Module C 203, ´High Performance Materials for Electrochemical Energy Systems' is comprised of the following course units:

	HPW	Semester
Lecture	2	SS
Laboratory Course	6	SS

This module will be offered by lecturers of Inorganic Solid-State Chemistry.

Course content:

The lecture introduces properties, processing and materials for electrochemical energy storage. Electrochemical fundamentals and cell concepts of modern accumulators and fuel cells are covered. The focus is on materials and how their properties affect the properties of the battery cells. The following aspects are covered:
i) Concepts of modern batteries and fuel cells
ii) Electrochemical cells and electrode processes (charge transfer and material transport)
iii) Cathode and anode materials: synthesis, structures, and properties
iv) Cathode and anode materials: phase diagrams and functional principles
v) Separators and electrolytes; ionic, superionic, and solid electrolytes
vi) Characterisation methods for battery materials including operando analyses.
In the practical course, students are introduced to methods and cell concepts with a focus on materials used in modern accumulators by means of selected examples. Under the guidance and supervision of experienced staff from the participating chairs, this includes electrochemical methods with a focus on structural and electronic characterisation in order to elucidate the different behaviour of the materials used in terms of crystal structures (diffraction, structure refinement) and local structure (NMR, PDF, EXAFS). Operando analytics is used as a tool to observe the cells at "work" and thus draw conclusions about the material selection.

Entrance requirements:

None

Assessment:

A written or oral examination covering the content of the lecture amounts to 5 CP and the quality of the lab course to 2/4 CP. Lab. course assessment results from the quality of syntheses, characterization, and discussion of results. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Given 15 weeks per semester this leads to 60 hours workload. For the lab course 120/180 hours has to be considered. Together with 30 hours for the preparation of the final examination a total workload of 210/270 hours for the whole semester results.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 103: Electrochemical Energy Systems and Energy Conversion

Learning objectives:

Students are familiarised with the possibilities and applications of modern electrochemical energy systems and energy conversion.

Course units and temporal allocation:

Module C 103, 'Electrochemical Energy Systems and Energy Conversion' is comprised of the following course units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by lecturers of Physical Chemistry II and III.

Course content:

Course contents: The lecture deals with properties, processes and interfaces for electrochemical storage and conversion of energy. The focus is on electrochemical fundamentals and general cell concepts as well as modern semiconducting electrodes and electrochemical analysis and electrocatalysis. The following aspects are covered:
i) General electrode processes (electron transfer, material transport)
ii) Overview of electrochemical cells
iii) Electrochemical analysis such as cyclic voltammetry and impedance spectroscopy
iv) Electrocatalysis and photoelectrochemistry (water splitting, ...)
vii) Methods for operando analytics.
In the ***laboratory course***, the students are familiarised with the presented measurement methods, cell concepts and the materials used in them on the basis of selected examples. Under the supervision of experienced staff of the respective chairs, this includes in particular electrochemical characterisation methods for investigating the properties and modes of operation of electrochemical cells, electrodes and systems.

Entrance requirements:

None

Assessment:

A written or oral examination covering the content of the lecture amounts to 5 CP and the quality of the lab course to 2/4 CP. Lab. course assessment results from the quality syntheses, characterization, and discussion of results. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Given 15 weeks per semester this leads to 60 hours workload. For the lab course 120/180 hours has to be considered. Together with 30 hours for the preparation of the final examination a total workload of 210/270 hours for the whole semester results.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 104: Colloids and Interfaces

Learning objectives:

The course will provide knowledge about advanced physical chemistry of colloids and interfaces. The surface force dominating colloidal systems will be presented as well wetting phenomena and low-Reynold number hydrodynamics. The analytical technique to characterize colloidal and interfacial properties will be introduced and practically applied by the students.

Course units and temporal allocation:

Module P 104, 'Colloids and Interfaces' is comprised of the following course units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by lecturers of Physical Chemistry.

Course content:

The ***lecture*** will cover: The solid/liquid, liquid/liquid and liquid/gas interface as starting point. The diffuse layer at interfaces will be treated in detail, including differential double layer capacitance and Grahame equation. Surface forces, with a special emphasis on van der Waals forces, diffuse layer overlap, depletion forces and steric forces are fundamental for understanding and tuning colloidal interactions and are therefore central to lecture. These topics will be followed by adsorption phenomena at interfaces, including the adsorption of lipids and polymers. Ternary systems and Pickering emulsions represent an important addition for liquid/liquid interfaces and the formulation of colloidal interactions. Wetting phenomena with an emphasis solid/liquid interfaces and real-world systems represent a further topic of the lecture with important practical applications. The DLVO theory and its consequences for colloidal stability will be treated in detail. The final topic will be low-Reynold number hydrodynamics and microfluidics. Throughout the lecture, the analytical methods of colloid and interface science will be introduced, such a electrokinetic methods, scattering techniques, scanning probe techniques or electrochemical and titration techniques.

In the ***laboratory course*** the students will be introduced to the characterization of the interfacial and colloidal systems and familiarize with the concepts introduced in the lecture. The laboratory course will be based on methods, such as impedance spectroscopy, quartz micro balance, microfluidics, optical and scanning probe microscopy.

Entrance requirements:

none

Assessment:

A written or oral examination on the contents of the lecture and the laboratory course after the first semester. This amounts to 5 CP. A second grade is given for the laboratory course and amounts to 2/4 CP. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload:

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Given 15 weeks per semester this leads to 60 hours workload. For the lab course 120/180 hours has to be considered. Together with 30 hours for the preparation of the final examination a total workload of 210/270 hours for the whole semester results.

ECTS Credit points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 204: Advanced Methods in the Physical Chemistry of Polymers

Learning objectives:

The students will be introduced to theoretical and practical knowledge of advanced analytical tools.

Course units and temporal allocation:

Module C 204, 'Advanced Methods in the Physical Chemistry of Polymers' is comprised of the following course units:

	HPW	Semester
Lecture	2	SS
Laboratory Course	8	SS

This module will be offered by lecturers of Physical Chemistry

Course content:

The ***lecture*** will present new complex experimental techniques which can be used in the study of soft matter, such as Cryo-transmission electron microscopy, scanning electron microscopy, AFM-force spectroscopy, surface force apparatus (SFA), total internal reflection microscopy (TIRM), fluorescence microscopy techniques (e.g., fluorescence correlation spectroscopy), scattering methods (e.g., neutron spin echo techniques (NSE), grazing incidence small angle X-ray scattering (GISAXS)) and X-ray photon correlation spectroscopy (X-PCS).

The associated ***laboratory course*** will be done in the physical chemistry research groups and will introduce the use of advanced scattering and microscopy equipment.

Entrance requirements:

None.

Assessment:

An oral or written examination of the contents of the lecture after the second semester. This examination will amount to 5 CP. The laboratory course will be evaluated by the average of three independent grades: Practical performance, written report, and a seminar, and amount to 2/4 CP.

Workload:

In addition to the 2 HPW for the lecture, 2 hours are planned for individual studies. Accordingly, 4 additional hours are necessary for the preparation of the experiments and the protocol of the 8 HPW laboratory course. Given 15 weeks per semester, this adds up to 240 hours. Together with 30 hours for the preparation of the final examination, a workload of 270 hours for the whole semester is calculated.

ECTS Credit Points: 7/9*

* Depending on the start date, the module can be chosen in the 1st semester with a short laboratory course of 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 205: Materials for Sensors, Catalysis and Energy Conversion

Learning objectives:

Materials for sensors, catalysis and energy conversion are key components for increasing energy efficiency, for detecting emissions, and for reducing pollutants. In recent years, fuel cells have been continuously improved, exhaust gas purification catalysts have become more and more effective and gas sensors have become smaller, better and less expensive. This module not only deals with materials for sensor technology, catalysis, and energy conversion, but also addresses the system aspect. The working group is active in these fields and can therefore offer students an insight into current research areas.

Course units and temporal allocation:

Module C 205, 'Materials for Sensors, Catalysis and Energy Conversion' is comprised of the following course units:

	HPW	Semester
Lecture	2	SS
Laboratory Course	8	SS

This module will be offered by lecturers of the chair of Functional Materials.

Course content:

In the lecture, the basics of functional materials for sensor technology, catalysis and energy conversion are laid. It turns out that there are materials that are used due to their volume properties as well as materials for which inner or outer surfaces are decisive for their function. Based on these fundamentals, the application of these materials is given due consideration. The position of the material in the overall system plays an important role.

The associated ***laboratory course*** takes place in the working group of the chair of Functional Materials. Under the guidance of experienced scientists, the students learn how to manufacture materials and components, their electrical and catalytic characterization as well as the use and application of these materials. The use of the materials in the field of gas electrochemical sensors, of CO_2 reductions techniques, of materials for solar cells and/or or novel deposition techniques is particularly deepened.

Entrance requirements:

None.

Assessment:

An oral examination on the contents of the lecture and the laboratory course will amount to 5 CP. The laboratory course will be graded for 2/4 CP.

Workload:

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Accordingly, 4 additional hours are necessary for the preparation of the experiments and the protocol of the 8 HPW laboratory course. Given 15 weeks per semester this adds up to 240 hours. Together with 30 hours for the preparation of the final examination a workload of 270 hours for the whole semester is calculated.

ECTS Credit Points: ***7/9****

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 105: Stereoselective Organic Synthesis

Learning objectives:

Methods, concepts and reactions of modern stereoselective organic synthesis are taught at an advanced level.

Course units and temporal allocation:

Module C 105, 'Stereoselective Organic Synthesis' is comprised of the following units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6/8*	WS

This module will be offered by lecturers of Organic Chemistry

Course content:

In the lecture Stereoselective Organic Synthesis, **i**important reactions and methods of stereoselective organic synthesis are covered. In the first part, which deals with diastereoselective methods, the fundamentals of stereoselective synthesis are taught and methods for the selective construction of *E*- and *Z*-configured alkenes and of stereocentres (e.g. additions to α-chiral carbonyl compounds and alkenes, aldol additions) as well as auxiliary-mediated procedures for the synthesis of enantiomerically pure compounds are presented. The second part focuses on enantioselective catalytic methods: biocatalysis, organocatalysis, reduction and oxidation processes, allylation/crotylation and ring closure reactions. The knowledge imparted is deepened by means of examples of natural substance syntheses and industrial processes.

In the ***laboratory practical course***, individual aspects of stereoselective organic syntheses are taught by working on a current research project in one of the participating research groups. The results are summarized in a report and presented in a seminar lecture.

Entrance requirements:

none

Assessment:

A written or oral examination on the contents of the lecture amounts to 5 CP. A second grade is given for the laboratory course and amounts to 2/4 CP. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload:

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Given 15 weeks per semester this leads to 60 hours workload. For the lab course 120/180 hours have to be considered. Together with 30 hours for the preparation of the final examination a total workload of 210/270 hours for the whole semester results.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 106: Polymer Synthesis

Learning objectives:

The major objective of the module is to provide basic knowledge about the different polymerization methods and the theoretical background. In addition, the students learn about the synthesis and structure-property relation of selected engineering plastics and high performance polymers. In the laboratory course the students learn how to carry out polymerization reactions practically on the basis of selected experiments.

Course units and temporal allocation:

Module C 106, 'Polymer Synthesis' is comprised of the following units:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by lecturers of Macromolecular Chemistry

Course content:

The ***lecture*** provides broad knowledge of the basic polymerization techniques including radical polymerization, cationic and anionic polymerization, polycondensation, and poly- addition. Special emphasis is given to modern synthetic procedures. In addition, selected polymers for special applications like polyurethanes, polycarbonates, and fluoropolymers will be presented.

In the ***laboratory course*** the knowledge on the different polymerization techniques is intensified in selected experiments from the fields of copolymerization, controlled radical polymerization, anionic polymerization, and polycondensation. The prepared polymers will be characterized by methods such as GPC, MALDI-TOF and viscosimetry.

Entrance requirements:

none

Assessment:

An oral or written examination on the contents of the lecture. This examination will amount to 5 CP of the grade. A second grade is given for the laboratory course and amounts to 2 CP of the final grade. The kind of examination (written or oral) and the date are given at the beginning of the semester.

Workload:

In addition to the 2 HPW for the lecture 1 hour is planned for individual studies. Accordingly, 3 additional hours are necessary for the preparation of the experiments and the protocol of the 6 HPW laboratory course. Given 15 weeks per semester this adds up to 180 hours. Together with 30 hours for the preparation of the final examination a total workload of 210 hours for the whole semester is calculated.

ECTS Credit points: ***7****

* The module can only be chosen with a short laboratory course of 7 CP. Therefore, it may not be chosen by students beginning in the summer semester.

Module C 107: Biomaterials

Learning objectives:

This module focuses on bio-inspired materials and processes. The students will learn about structure, synthesis, and modification of biopolymers, including biomineralization. Furthermore, the students will gain a comprehensive insight in current research topics and industrial applications. The characterization and analysis of mechanical and structural properties of biomacromolecules also plays an important role in this module.

Course units and temporal allocation:

Module C 107 'Biomaterial' is comprised of the following courses:

	HPW	Semester
Lecture	2	WS
Laboratory Course	6	WS

This module will be offered by the chair of Biomaterials.

Course content:

A major objective of the **lecture** is the applications of nucleic acids, lipids, and proteins in nanotechnology, pharmacology, and industry. Furthermore, the course deals with the science behind the assembly of macromolecules, the biomineralisation process and their man-made imitations. Important characterization methods, such as field-flow fractionation, CD-, UV-, IR- and fluorescence spectroscopy, AFM, EM, HPLC, and mechanical testing are presented. Additionally molecular and microbiological methods and techniques are introduced.
The **laboratory course** puts the students in a position to apply these methods for instance on spider silk, mussel collagens, and yeast proteins.

Entrance requirements:

none

Assessment:

The module will be evaluated by an oral or written examination (5 CP) and the evaluation of the laboratory course consisting of the practical performance and a report (2/4 CP).

Workload:

In addition to 2 hours of lecture, 2 more hours are necessary for the preparation and the review of the lecture. This will add up to 60 hours for the entire semester. The laboratory course accounts for 120 hours. Furthermore, preparations for the examination are estimated to additional 30 hours. This adds to a sum of 210 hours.

ECTS Credit points: ***7/9****

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Please note that Biomaterials is thought in **German in the winter semester** and in **English in the summer semester** only. The laboratory course, however, is only offered in the winter semester.

Module C 206: From Macromolecule to Material

Learning objectives:

This module will enable the student to design polymers with well-defined structures, based on living/controlled polymerization techniques. The students will learn the solution and bulk properties of polymers with selected architectures.

Course units and temporal allocation:

Module C 206, ‘From Macromolecule to Material’ is comprised of the following course units:

	HPW	Semester
Lecture	2	SS
Laboratory Course	8	SS

This module will be offered by lecturers of Macromolecular Chemistry

Course content:

The ***lecture*** consists of two parts. In the first part the mechanisms of living/controlled polymerizations (anionic, cationic, radical, coordinative, ring-opening) will be discussed in great detail. The second part will cover Macromolecular Engineering, i.e. the synthesis and properties of various polymer architectures will be discussed in detail, e.g. block and graft copolymers, star-branched and hyperbranched polymers, organic and hybrid nanoparticles.

The associated ***laboratory course*** will be performed in one of the macromolecular chemistry research groups in collaboration with PhD students and post-docs. It will cover the synthesis and characterization of given polymer structures.

Entrance requirements:

Participation in C 106 (Polymer Synthesis) is highly recommended.

Assessment:

An oral (or written) examination on the contents of the lecture after the second semester. This examination will amount to 4 CP of the grade. The laboratory course will be evaluated by the average of three independent grades: Practical performance, written report, and a seminar and amount to 3/5 CP of the grade.

Work load:

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Accordingly, 4 additional hours are necessary for the preparation of the experiments and the protocol of the 8 HPW laboratory course. Given 15 weeks per semester this adds up to 240 hours. Together with 30 hours for the preparation of the final examination a workload of 270 hours for the whole semester is calculated.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 207: Applied Functional Polymers

Learning objectives:

During the last decades organics and polymers have successfully entered and opened new application fields and replaced other materials. In this module the students will learn about the design, synthesis, and structure-property relation of high performance and specialty polymers. Since a number of research groups at the University of Bayreuth are active in this research area the students will be introduced to cutting edge science in this field.

Course units and temporal allocation:

Module C 207 ‚Applied Functional Polymers' is comprised of the following course units:

	HPW	Semester
Lecture	2	SS
Laboratory Course	8	SS

This module will be offered by lecturers of Macromolecular Chemistry

Course content:

In the ***lecture*** the design, synthesis, and structure-property relation of organic functional materials and specialty polymers will be discussed with respect to advanced applications such as optics, information storage, solar cells, organic electronics, photolithography, and display technology.

The associated ***laboratory course*** will be done in one of the macromolecular chemistry research groups working on high performance organic materials and specialty polymers. The students will be introduced into the synthesis of new materials as well as their detailed physical characterization and their application in devices.

Entrance requirements:

None

Assessment:

An oral (or written) examination on the contents of the lecture after the second semester. This examination will amount to 50 % of the grade. The laboratory course will be evaluated by the average of three independent grades: Practical performance, written report, and a seminar and amount to 50 % of the grade.

Work load:

In addition to the 2 HPW for the lecture 2 hours are planned for individual studies. Accordingly, 4 additional hours are necessary for the preparation of the experiments and the protocol of the 8 HPW laboratory course. Given 15 weeks per semester this adds up to 240 hours. Together with 30 hours for the preparation of the final examination a workload of 270 hours for the whole semester is calculated.

ECTS Credit Points: **7/9***

* Depending on the start date, the module can be chosen in the 1st semester with short laboratory course 7 CP or in the 2nd semester with a longer laboratory covering 9 CP.

Module C 210: Research Proposal

Learning objectives:

This module is aimed at acquiring basic knowledge in planning and drafting a scientific project proposal based on the existing knowledge in a specific research area. Here the students learn to prepare a sound proposal both written and oral, which helps them in planning their master thesis.

Course units and temporal allocation:

Module C 210 ‚Research Proposal' is comprised of the following course units:

	HPW	Semester
Writing a research proposal	5	WS/SS
Seminar on research topic	1	WS/SS

This module will be offered by all lecturers of the Master Program Polymer Science

Course content:

Before starting the master thesis, the students work on a research proposal by selecting a research topic, formulating the state of the art in the literature, identifying the main objectives of the research plan, and explaining the work plan and targets based on proposed experiments. Additionally, the written research plan will be presented in a seminar in order to improve the capabilities of presentation techniques and scientific discussion. In this way the students gain experience to work more independently on research topics and to formulate well-focused research proposals.

Entrance requirements:

None.

Assessment:

Written research plan (3 CP) and oral presentation and discussion (2 CP).

Workload:

For the written research plan which covers work on literature research a total of 120 hours are envisaged, whereas the seminar on the research proposal including preparation of seminar and oral presentation results in 30 hours, total work load being 150 hours.

ECTS Credit Points: 5

Module C 301 and 302: Advanced Laboratory Module I and II

Learning objectives:

The objective of this module is to further enhance the laboratory and science skills of the students in selected advanced fields of materials chemistry and catalysis. The students will be introduced to current research topics investigated in one of the materials chemistry and catalysis research groups at the University of Bayreuth. In addition, the students will improve their ability to work in a team and their skills to present their research.

Course units and temporal allocation:

Module C 301 and 302 ‚Advanced Laboratory Module I and II' is comprised of:

	HPW	Semester
Material´s chemistry and catalysis research project	19	WS/SS
Group seminar presentation	1	WS/SS

This module will be offered by all professors of the Master Program Materials Chemistry and Catalysis.

Course content:

The course covers a selected topic of current research within one of the research groups involved in the Master Program Materials Chemistry and Catalysis. The module includes experiments in the lab, literature search, participation at group seminars, and the presentation of the research results in form of a report and a seminar with discussion.

Entrance requirements:

The successful completion of a basic module related to the topic of the Advanced Laboratory Module is highly recommended.

Assessment:

The laboratory experiments will be evaluated by the average of three independent grades: Practical performance, written report, and seminar.
For advanced laboratory modules completed at universities abroad or in industry, the equivalence of the work performed in terms of scope and content must be confirmed in writing by the respective supervisor. In addition, a graded record of this must be submitted to the examination committee. If intellectual property issues might be involved, it is wise to resolve them prior to start by talking to a local adviser.

Workload:

350 hours are projected for the laboratory experiments, 100 hours for the literature search, the report, and the seminar. This adds up to a total of 450 hours.

ECTS Credit points: 15

Module C 400: Master Thesis

Learning objectives:

The students work independently on a research project under the guidance of a faculty member and write the results and discussion in the form of a thesis.

Course units and temporal allocation:

Module C 400 ‚Master Thesis' comprises the following:

	Hours	Semester
Research project and written thesis	900	WS/SS

This module will be offered by all lecturers of the Master Program Materials Chemistry and Catalysis

Course content:

The topic of the master thesis is based on a current research activity of the selected research group.

Entrance requirements:

A successful completion of 45 ECTS and the Module C 210 'Research Proposal' (5 ECTS) is required. Moreover, completion of one Advanced Laboratory Module is highly recommended.

Assessment:

The master thesis written and submitted at the end of the research work will be evaluated by two reviewers independently.

Workload:

Master thesis covers work on literature research, experimental work and the formulation of all results and discussion amounting to a total workload of 900 hours.

ECTS Credit Points: ***30***