MODULE DESCRIPTIONS

Advanced Polymer Chemistry

Standard workload: 5 ECTS

Learning outcomes:

Students acquire highly specialised knowledge in the field of macromolecular chemistry and, after successfully completing the module will be able to:

- Design and manufacture polymers with a desired property profile (e.g. thermoplastics, elastomers, duromers) by selecting the required polymerisation technology
- describe and analyse the production and structure of plastics
- Apply methods for the physical/chemical characterisation of polymers (spectroscopic and chromatographic methods, viscometry)
- Establish correlations between the reaction process and the material properties of the product obtained and interpret the results

Expected prior knowledge:

Basic knowledge of organic and macromolecular chemistry and mastery of simple laboratory techniques

Content requirements for registration for the module: none

Limited number of participants: 24

Advanced Polymer Physics

Standard workload: 5 ECTS

Learning outcomes

After successfully completing the module, students will have:

- In-depth knowledge of polymer physics based on the latest scientific findings
- Highly specialised knowledge regarding the design and adaptation of properties and performance of plastics (incl. components and parts)
- Specialised skills for predicting basic polymer properties based on structural parameters
- Critical awareness of the variability of polymer properties depending on external factors and stimuli

Expected prior knowledge:

Contents of the courses Fundamentals of Polymer Physics, Applied Polymer Physics, Fundamentals of Materials 2, Macromolecular Chemistry, Organic Chemistry

Content requirements for registration for the module: none

Limited number of participants: 30

Structural Modelling and Simulation

Standard workload: 5 ECTS

Learning outcomes

After successfully completing the module, students can:

- precisely define a technical problem
- find suitable analytical and numerical models for a technical problem
- evaluate different modelling approaches (analytical, numerical)
- select and apply adequate material models for realistic technical problems
- plan suitable experiments to validate theoretical models

Expected prior knowledge:

Fundamentals of finite elements, use of the FEM software Abaqus CAE, fundamentals of elastic, viscoelastic, elasto-plastic and hyperelastic material models, basic understanding of the mechanics of composite materials (micromechanical and homogenised consideration), basic knowledge of contact and friction. See contents of the following courses:

- Mechanics of plastics (polymers)
- Mechanics of composite materials
- Finite element method for KT (Finite element method for KT)

Content requirements for registration for the module: none

Restriction on number of participants: none

Lab in Processing of Polymers and Composites

Standard workload: 5 ECTS

Learning outcomes

In this practical course, students acquire advanced practical knowledge of various polymer and composite processing techniques with the aim of gaining an in-depth understanding of these techniques, the differences and applicability of these technologies and gaining practical experience in the laboratory.

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

- Explain the specific principles of the different processing techniques and the associated applications and challenges at a scientific level
- Operate the most common polymer processing machines and measuring equipment at an advanced level
- Write a structured experimental report on a selected polymer processing technology according to the standards of scientific writing
- Present a selected polymer processing technology in a professional presentation to other students and teachers

Expected prior knowledge:

- Basic key knowledge, skills and competences for engineers (mathematics, physics, chemistry, technical mechanics)
- Knowledge, skills and competences in digital sciences and statistics
- Chemical and material-physical fundamentals of polymers

- Basic knowledge of constituents, materials and processing technologies for the production of components made of plastics and fibre-plastic composites.

Content requirements for registration for the module: none

Limited number of participants: 30

Polymer Sustainability

Standard workload: 5 ECTS

Learning outcomes

After successfully completing the module, students will have:
- Critical awareness of the complexity of the sustainability of plastics and the associated diversity of perspectives and emotions
- Specialised skills for critical reflection and evaluation of the opportunities and challenges of plastics in the context of sustainable development
- Highly specialised expertise in the development of future plastic materials, products and processes from the perspective of green engineering and sustainability

Expected prior knowledge:

Contents of the course Fundamentals of Materials 2

Content requirements for registration for the module: none

Restriction on number of participants: none

Digital Skills in Polymer Science

Standard workload: 5.05 ECTS

Learning outcomes:

After successfully completing the module, students can:
- understand and correctly use the basic syntax and different data types in Python
- Name data principles and challenges in connection with material data and explain them with examples
- Extract data from material databases
- Use Python libraries for scientific data analysis
- Write scripts for the automatic analysis and visualisation of large data sets for use in theses and scientific publications
- Explain machine learning algorithms used in polymer science and evaluate their suitability for specific applications
- Apply machine learning algorithms and evaluation methods to problems from plastics technology.

Expected prior knowledge:

Basic knowledge of materials and their properties as well as experience with a programming language.
Basic knowledge of polymer processing, polymer physics, polymer chemistry and mechanics of

polymers (see specialized courses in the polymer engineering branch of the Bachelor's programme in Materials Science and Technology).

Content requirements for registration for the module: none

Restriction on number of participants: none

Science and Responsibility

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students will have:

- Highly specialised knowledge of conducting complex scientific research, including the definition of research questions, the review and critical evaluation of scientific literature, the development of a suitable research programme for the Master's thesis, the critical evaluation and presentation of the results obtained, scientific "story telling" and the correct citation of literature
- Critical awareness of good scientific practice, correct citation and avoidance of plagiarism as a solid basis for scientific work
- Specialised skills and responsibilities for the design, preparation and defence of scientific papers and publications that present and discuss the results and conclusions of complex research and development tasks.

Expected prior knowledge:

- Basic 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
- Initial experience in conducting scientific research

Content requirements for registration for the module: none

Restriction on number of participants: none

Technical Biopolymers

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students will have:

- Highly specialised knowledge that is linked to the latest findings in the field of technical biopolymers and creates the basis for innovative approaches and research ideas
- Critical awareness of knowledge issues in the field of engineering biopolymers, including current limitations of their applicability, ecological aspects and future potentials
- Specialised skills for developing strategic approaches and ideas for carrying out complex research and development tasks

Expected prior knowledge:

Contents of the courses

- Fundamentals of Polymer Physics
- Applied Polymer Physics
- Fundamentals of materials 2
- Macromolecular chemistry

Content requirements for registration for the module: none

Limited number of participants: 25

Polymers in Medical Devices

Standard workload: 5 ECTS

Learning outcomes:

Students acquire highly specialised knowledge in the field of additive manufacturing of medical devices.
After successfully completing the course, students can:

- Create requirement profiles for plastics in different areas of medical technology
- Explain the principles and functionality of common additive printing processes
- Explain the principles and functionality of chemical analysis methods such as HPLC-MS, GC-MS and ICP-MS
- Explain and describe the mechanisms of photopolymerisation (radical)
- Explain the procedures and methods for determining the biocompatibility of medical devices
- Select additive processes and materials for the manufacture of medical devices

Expected prior knowledge:

Basic knowledge in the field of macromolecular biology

Content requirements for registration for the module: none

Restriction on number of participants: none

Chemistry of Biobased Materials

Standard workload: 5 ECTS

Learning outcomes:

Students acquire a highly specialised knowledge of the physical and chemical principles for the production and formulation of bio-based materials. After successfully completing the module, students will be able to

- Assess which "classic" plastics can be replaced by plastics based on biopolymers or bio-based polymers
- Derive structural and property relationships of bio-based plastics
- Describe, correctly select and apply manufacturing processes and processing methods for bio-based polymers
- Apply post-treatment and technical test procedures
- The students have a deep insight into the possibilities of chemical, material and mechanical recycling of bio-based plastics and have the opportunity to gain a direct insight into the industrial world to illustrate the subject matter

Expected prior knowledge:

Basic knowledge of organic and macromolecular chemistry as well as the processing and testing of polymers

Content requirements for registration for the module: none

Restriction on number of participants: none

Applied Rheology of Polymers

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students can:

- Explain the scientific and technical principles of rheology
- Explain the different rheometers and select them for the various requirements and define the advantages and disadvantages
- Analyse the basics, applications and differences between shear rheology and extensional rheology
- Explain the different tensors and the connection with the law of matter
- Show the effects of normal stresses
- Visualise and describe the most important types of flow
- Present and explain typical flow and viscosity curves of flowable systems and draw curves from practice
- Describe and explain the types and measuring principle of high-pressure capillary rheometers
- Explain the calculation principles for Newtonian and wall-bound fluids
- Calculate according to the evaluation steps for structurally viscous fluids
- Apply the corrections according to Weißenberg/Rabinowitsch and Bagley
- Explain the types and measuring principle of rotational vibration rheometers
- Apply the calculation principles for cone/plate and plate/plate rheometers to perform calculations
- Explain the fundamental processes of oscillation measurements
- Apply the oscillation measurements depending on the area of application and interpret the results
- Explain the calculation principles for representative viscosity and use them to perform calculations
- Explain different approaches to viscosity and apply them
- Explain and apply the Cox-Merz rule

- Explain the error influences during measurements with the capillary rheometer
- Explain and apply the methods for determining the pressure dependence of viscosity during measurements with the capillary rheometer
- Explain the principle of temperature shift for the flow and viscosity curve
- Apply approaches for the mathematical description of the temperature dependence of viscosity
- Calculate the temperature shift of the viscosity curve
- Explain and describe the meaning of the terms rheopexy and thixotropy
- Explain and describe practical application examples for time-dependent viscosity
- Explain and describe the influence of the average molar mass and molar mass distribution on viscosity
- Explain and describe the influence of thermomechanical shear history on viscosity
- Explain the influence of the thermomechanical shear history on the flow behaviour of PVC-P
- Explain the definition of fillers
- Name different fillers and additives and explain their properties
- Explain the influence of different fillers on viscosity
- Explain the mechanisms for the occurrence of wall slip and calculate wall slip
- Explain the evaluation methods with regard to wall slip and apply them

Expected prior knowledge:

- Mathematics
- Basics of plastics processing

Content requirements for registration for the module: none

Limited number of participants: 15

Polymer Recycling Technology

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students will be able to

- Name different manufacturing processes for plastics and identify suitable processing techniques.
- Explain the specific processing methods for thermoplastics, thermosets and elastomers.
- Explain the challenges involved in processing recycled materials.
- Identify important markets and consumption statistics for the main polymer types, supplemented by typical application examples.
- Explain the legal framework for plastics recycling and specify its scope of application.
- Distinguish between different recycling methods and describe the main processes of each method.
- Analyse ecological aspects of plastics recycling and interpret ecological assessments in a well-founded manner.
- Evaluate potential future developments in raw materials, production, applications and recycling for different classes of polymers based on current research and advances in processing techniques.

Expected prior knowledge:

Contents of the Bachelor's degree programme in Materials Science and Technology

Content requirements for registration for the module: none

Restriction on number of participants: none

Circularity of fibre-reinforced polymer composites

Standard workload: 5 ECTS

Learning outcomes:

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

- Basic understanding of the objectives and strategies of recycling and waste management
- Specialised knowledge of the specific features of materials and components made of fibre-plastic composites in this context and the associated challenges in the circular economy,
- Specialised knowledge on the variety of possibilities in the field of reuse, conversion, repair, processing and joining technology for fibre-plastic composites,
- Highly specialised knowledge of the thermal, chemical, mechanical and biological recycling of fibre-plastic composites as well as the quality and homogeneity of the resulting fractions with regard to their recycling,
- Specialised knowledge of life cycle analysis in the circular economy of fibre-plastic composites, taking into account the processing and recycling processes used.

Expected prior knowledge:

- Basic key knowledge, skills and competences for engineers (mathematics, physics, chemistry, technical mechanics)
- Knowledge, skills and competences in digital sciences and statistics
- Chemical and material-physical fundamentals of polymers
- Basic knowledge of constituents, materials and processing technologies for the production of components made of fibre-reinforced plastics.

Content requirements for registration for the module: none

Restriction on number of participants: none

Industrial Polymer Chemistry

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students will have a high level of scientific and technical understanding of polymer chemistry from the perspective of an industrial chemist. Particular consideration is given to the aspects of raw materials, polymerisation and processing methods as well as the needs-based additivation of plastics.
Students are able to work independently:

- derive the processing and utilisation properties from the molecular structure
- create basic recipes
- describe reactions and
- Develop and apply additive systems
- characterise and test the formulations developed

Expected prior knowledge:

Basic knowledge in the field of organic and macromolecular chemistry as well as in the processing and testing of polymers

Content requirements for registration for the module: none

Restriction on number of participants: none

Injection Moulding Technology

Standard workload: 5 ECTS

Learning outcomes:

The learning outcome is an advanced knowledge of injection moulding technology.
After this course, students will be able to

- Name, outline and explain the most important components of an injection moulding machine and an injection mould in detail
- Provide an overview of various special injection moulding techniques and explain how they work and their applications
- Explain the most common injection moulding defects (causes and remedies)
- Experimentally apply the principle of test planning (factorial test plans) on an injection moulding machine in order to analyse the influence of process settings on part quality
- Carry out an injection moulding simulation with commercial software including the interpretation of results for the standard injection moulding process
- Present and discuss important simulation results and the machine selection in front of colleagues and teachers

Expected prior knowledge:

- Basic knowledge of polymer rheology (shear flow, viscosity curve, structural viscosity, temperature dependence)
- Basic knowledge of the conservation equations of mass, momentum and energy (simplifications for special problems)
- Overview of the components and mode of operation of a standard injection moulding machine (clamping unit, injection unit)
- Main functional units of an injection mould
- Injection moulding cycle
- Injection moulding process in the pvT diagram
- Heat balance of an injection mould
- Process-related component properties (orientations, residual stresses)

Content requirements for registration for the module: none

Limited number of participants: 20

Extrusion Technology

Standard workload: 5 ECTS

Learning outcomes:

Advanced knowledge of machines and systems for the extrusion of polymers and a critical understanding of the layout and design of extrusion screws through the specialised derivations and applications of the analytical models of the different extruder zones.
Upon successful completion of the course, students will have acquired the following specialised knowledge, skills and competences:

- They are able to explain the complex scientific and technical principles of polymer extrusion.
- They can put together optimised extrusion systems, selecting the different system components and their designs and assessing their influence on each other.
- They are able to assess the factors influencing the system components on the end product and can understand and select specific new applications.
  They will be able to explain the most commonly used technologies and systems for the extrusion of polymer products.
- They are able to put together optimised extrusion systems, selecting and applying new findings and processes.
- They can explain, analyse and apply the working methods and optimisation options of single and multi-screw extruders.
- They can develop new processes by applying the isothermal theory of flow properties in extrusion and derive the resulting velocities, volume flows, but also the throttling coefficient, the dwell time, the drive power and the operating point.
- They understand the derivation and principles of melting and solids transport, as well as the underlying material properties.

Expected prior knowledge:

Mathematics in general and in particular the solution of differential equations.
Advanced knowledge of the rheology of plastics.
Critical understanding of plastics processing, in particular the theory and mathematical application of conservation laws in plastics processing and an understanding of the thermodynamic and rheological properties of the material properties of the materials.

Content requirements for registration for the module: none

Restriction on number of participants: none

Processing of fibre-reinforced composites

Standard workload: 5 ECTS

Learning outcomes:

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

- Specialised knowledge of the basic components of fibre-plastic composites, the variety of materials and architectures of fibre-based reinforcement structures and the thermoplastic and thermoset matrix materials typically used
- Specialised knowledge of processes, plant and processing techniques to produce fibre-reinforced polymer semi-finished products and components made of fibre-plastic composites from the constituents
- Critical awareness of the relevant aspects of process selection, taking into account the requirements of the application, the processing-relevant properties of the materials used as reinforcing structure and polymer matrix as well as specifications regarding fibre orientation and production quantity.

Expected prior knowledge:

- Basic key knowledge, skills and competences for engineers (mathematics, physics, chemistry, technical mechanics)
- Knowledge, skills and competences in digital sciences and statistics
- Chemical and material-physical fundamentals of polymers.

Content requirements for registration for the module: none

Restriction on number of participants: none

Mechanical Response of Composites

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students can:

- Name current test and analysis methods for layered composite materials with regard to stiffness, strength and damage assessment.
- Select and apply appropriate methods for specific problems.
- Evaluate the influence of microstructure on material and component behaviour.
- Evaluate the influence of damage mechanisms on failure behaviour.
- Evaluate the influence of temperature, humidity and manufacturing processes.

Expected prior knowledge:

Basic knowledge of materials science of polymers, testing of polymers, mechanics of composites and FEM modelling; programming in Python, use of Abaqus CAE. Reference to the following courses:

- Mechanics of Composite Materials
- Structural Modelling and Simulation
- Digital Skills in Polymer Science (Part I - Python Programming)
- Fundamentals of polymer physics

Content requirements for registration for the module: none

Limited number of participants: 21

Predicting Mechanical Failure in Polymer Components

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students can:

- Apply continuum-mechanical approaches to predict the service life and reliability of plastic components under monotonic, static and especially cyclic loads.
- Select and apply suitable material models and simulation strategies for different load scenarios.
- Development of independent test concepts and generation of the required property parameters as input parameters for material models and simulation concepts, taking into account special processing characteristics.
- Establishment of validation concepts for the postulated prediction models and implementation of sub-components and component tests.

Expected prior knowledge:

- Comprehensive knowledge of mechanics, physics and materials testing of polymers
- Basic knowledge of elastic, visco-elastic, visco-plastic and hyper-elastic material models
- Basic knowledge of FEM theory and Abaqus CAE software.

Content requirements for registration for the module: none

Restriction on number of participants: none

Fracture Mechanics of Polymers

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students can:

- Understanding the principles of fracture mechanics (FM)
  Students will be able to understand the highly specialised principles such as stress intensity factor, energy release rate, J-integral, crack tip opening displacement, essential work of fracture and the effects of different test conditions on the behaviour of polymers.
- Selection of the appropriate FM methodology
  Students have a critical awareness of the selection of appropriate FM methods based on the behaviour of the material under investigation under a given set of boundary conditions.
- Finite element-based determination of stress intensity factors
  Students are able to derive the development of a stress intensity factor as a function of the crack length within a component on the basis of finite element simulations.
- Experimental determination of FM-based data
  The student is able to experimentally determine critical (KIC, GIC, JIC, CTOD) and subcritical (crack kinetics / Paris Law) fracture mechanics values using advanced skills and to check their validity according to the chosen method
- Application of fracture mechanics-based service life estimation
  Students have specialised problem solving skills and are able to perform a linear-elastic fracture mechanics based fatigue life estimation of a component consisting of the selection of test parameters, the experimental determination of a crack growth law, the finite element based determination of the evolution of a stress intensity factor as a function of crack length in an arbitrary component and the combination of both to a final fatigue life. In addition, students are able to gain new knowledge in order to develop new, customised methods if required by the problem.

Expected prior knowledge:

- Understanding of basic mechanical principles
- Finite element methods
- Use of mechanical laboratory equipment and rudimentary application of a programming language such as Python

Content requirements for registration for the module: none

Limited number of participants: 25

Functional Integrity of Polymer Products

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students can

- Name degradation processes and stabilisation approaches of polymers
- Identify internal and external causes of degradation
- Carry out ageing characterisations and determine suitable degradation indicators

- Analyse cases of damage and derive corresponding degradation mechanisms
- Select suitable environmental simulation methods to simulate ageing effects in the laboratory
- Adapt methods for service life estimation

Expected prior knowledge:

- Advanced polymer physics
- Advanced polymer chemistry

Content requirements for registration for the module: none

Restriction on the number of participants: 0

Coatings and Adhesives

Standard workload: 5 ECTS

Learning outcomes:

Students acquire highly specialised knowledge in the field of coatings and adhesives. After successfully completing the module, students will be able to

- describe the chemistry of coatings and adhesives and the structure of coating systems
- describe the mechanisms of adhesion and causes of failure
- Select coating systems and adhesives with a desired property profile and apply them in practice
- apply the basic chemistry of binders
- describe and apply test methods for adhesives, coatings and coating systems

Students also acquire in-depth knowledge of ecological goals and future trends in coating and adhesive research and have the opportunity to gain a direct insight into industrial practice to illustrate the course content.

Expected prior knowledge:

Basic knowledge in the field of organic chemistry and macromolecular chemistry

Content requirements for registration for the module: none

Restriction on number of participants: none

Photoreactive Polymers

Standard workload: 5 ECTS

Learning outcomes:

Students acquire a highly specialised knowledge of the application of UV light in the field of polymerisation, polymer cross-linking and structuring of plastics. After successfully completing the module, students will have theoretical and practical knowledge in the following areas:

- Explanation and presentation of the mechanisms of photopolymerisation (radical, ionic)
- Selection of photoinitiators for a planned application
- Independent formulations for UV coatings
- Description of the behaviour of plastics under ionising radiation
- Creating stereolithographic structures with photoresists
- Prevention of photooxidative damage in engineering plastics through suitable additives

- Characterisation techniques (infrared spectroscopy, UV/VIS spectroscopy, determination of surface energy)
  In addition, students have in-depth knowledge of the chemistry and application of switchable polymers and have the theoretical basis to
- Click reactions for the synthesis of functional polymers
- Utilise reversible organic reactions for the synthesis of functional polymer systems
- Produce dynamic polymer networks
- Apply chemical and physical healing mechanisms in polymers
- Produce and use polymers with shape memory
- Produce functional polymer structures using 4D printing processes

Expected prior knowledge:

Basic knowledge in the field of organic chemistry and macromolecular chemistry

Content requirements for registration for the module: none

Limited number of participants: 12

Lightweight Design and Optimization

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students will have:
- Highly specialised knowledge of basic lightweight construction principles and optimisation methods.
- The ability to apply these principles to specific problems.
- The ability to select suitable methods for specific issues.

Expected prior knowledge:

Basic knowledge of structural and solid mechanics and FEM modelling; (use of Abaqus CAE/Altair Hyperworks).
Reference to the following courses:
Module Structural Modelling and Simulation

Content requirements for registration for the module: none

Restriction on number of participants: none

Additive Manufacturing with Polymers

Standard workload: 5 ECTS

Learning outcomes:

After successfully completing the module, students can:
- Report on the motivation for AM
- Explain the historical development and context
- Describe the economic impact
- Provide an overview of traditional production processes
- Explain the AM systematisation
- Explain the basics of design for AM

- Describe phases of AM
- Explain the classification of AM processes
- Describe the basic AM processes
- Explanation of the technology of VPP, PBF, MEX, BJ and MJT
- Describe applications for VPP, PBF, MEX, BJ and MJT
- Provide an overview of the special features of VPP, PBF, MEX, BJ and MJT
- Explain the limitations of VPP, PBF, MEX, BJ and MJT
- Explain the possibilities of AM for pharmaceutical applications.

In the laboratory courses, students will acquire practical knowledge of various additive manufacturing techniques with the aim of better understanding these techniques, the differences and applicability of these technologies and gaining practical experience in the laboratory.

Expected prior knowledge:

Basic knowledge corresponding to the Bachelor in Polymer Engineering and Science is required, in particular the basics of polymer processing and the basics of the physics and chemistry of polymers such as:

- Mathematics
- In-depth knowledge of the rheology of polymers
- Fundamentals of polymer processing such as the theory and application of
- Conservation equations for mass, momentum and energy for the mathematical description of plastics processing and description of the rheological and thermodynamic material behaviour of polymers.

Recommended courses:

- Injection Moulding Technology
- Extrusion Technology

Content requirements for registration for the module: none

Restriction on number of participants: none