AC
Angewandte Chemie

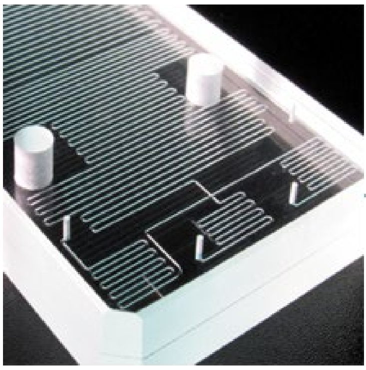
Module Compendium

for the Master's Degree Program

Master of Science

Polymer & Process Analytical Chemistry

Valid as of July 2022
School of Applied Chemistry

"Combining reaction and detection in multiphase microfluidic flow is becoming increasingly important for accelerating process development in microreactors. Spectroscopy with microreactors for online process analysis under gas–liquid and liquid–liquid segmented flow conditions is only one excited topic in the study program"

Hochschule Reutlingen
Reutlingen University

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Preliminary Remarks

This module compendium serves the purpose of providing students and instructors a detailed and comprehensive description of the curriculum of the degree program Master of Polymer & Process Analytical Chemistry.

The module descriptions present the module goals and intended results of study as well as the contents of the individual courses. Furthermore, all information necessary for academic success is given in the module descriptions. They are also included in the diploma supplement to the master’s degree program.

If you have any questions regarding several modules or the course of studies, please contact the office of the Dean of the School of Applied Chemistry.

If you have questions regarding a particular module, please contact the responsible module coordinator which is nominated in the individual course description.

If you have questions regarding a particular course, please contact the instructor.

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Introduction

Objectives of this course of studies

(1) The postgraduate degree program leads to a further qualification of university graduates, who have good chemical and analytical-chemical and polymer-chemical knowledge as the result of successfully completed undergraduate chemistry-oriented studies.

(2) The aim of the course is to provide students with both a deepening of their methodological knowledge as well as their technical knowledge in the field of polymer chemistry, analytical chemistry and particularly the process analytics. Thus, they are ideally prepared for a professional career or for further education e.g. promotion (PhD). This is achieved through the close link between the teaching of scientific principles on the one hand with a strong project-oriented approach on the other.

(3) In addition to the broader understanding of the industrial importance of polymer chemistry and technology as well as chemical analysis, students acquire the practical knowledge and the necessary skills to successfully design and apply polymer technological and process analytical methods. The offered "soft skills" modules aim to the better understanding of the industrial environment. Secondly, they mainly serve to encourage independent, scientific work, competence for problem solving, cooperative activity in a team, scientific communication and the holistic understanding of material science and process analytics.

(4) The independent scientific work of the students shall be achieved through an extended research project in a team, which lasts two semesters. The thesis shall be performed generally in the industry or at research institutes.

(5) On the basis of this course of study, students will learn to perform independent work in the industry and they are equipped with the necessary skills for researchers. The employment area comprises the development and characterization of materials, products and analytical methods as well as the adaptation and development of those in the industrial use.

Overview of the course of studies

The curriculum of the master degree program for Polymer & Process Analytical Chemistry comprises 3 semesters. The diploma is a professional qualification and enables graduates of Polymer & Process Analytical Chemistry with a master’s degree in natural science to work in industry or in academia.

Important structural elements of the course of studies are

- two modules providing the essential scientific skills and methods in the first semester
- subject specific elective and mandatory modules in the first two semesters
- one module which deals with management skills
- one module of project-oriented-learning in the second semester
- a master’s thesis, to be written within 6 months during the third semester.

In the first semester students will learn about relevant scientific methods that will be applied in the project-oriented learning in the second semester.

In the first two semesters, students will achieve elementary knowledge in the field of polymer chemistry, material science, process analytics, process control, and in the subject of industrial technology management.

In the second semester, students will deepen their skills in scientific methods in the field of information retrieval and evaluation and will apply these skills in the project-oriented learning. They work in independent teams at Reutlingen University on up-to-date issues of the industry. Higher-level subjects will be incorporated in a research seminar and complete the course of studies.

In the third semester, the individual master’s thesis will be written.

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European Credit Transfer and Accumulation System (ECTS)

The Ministry for Science, Research and Art Baden-Württemberg and the Conference of Ministers of Culture require the curriculum of study to be divided into modules. Students' performance is recorded by means of the „European Credit Transfer and Accumulation System“ (ECTS). In order to compare the performance of students at various institutions of higher learning — also foreign institutions — the ECT system is based not on the number of course hours per week, but rather on the time that students are required to invest in learning. In this way, student performance can be more objectively compared throughout Europe.

Full-time students can achieve 60 ECTS credit points per academic year. This approximates an average workload of 1800 hours of study. A credit point corresponds to 30 hours workload for a student of average intelligence and aptitude, whereby the workload includes the time during which the student attends class and his/her study time outside of class. Class time is given as weekly number of hours (à 60 minutes) per course (WH).

Example:

WH*	Class attendance	Study time	Workload	Credit points
2	30 h	60 h	90 h	3

WH* = 1 WH equals 15 hours per semester, which normally consists of 15 weeks.

Students can only obtain the ECTS points if the required exams have been successfully and verifiably absolved. Credit points are awarded according to the “all or none” principle.

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Overview of the modules in the course of studies

Module No.	Module name	module components	Semester	WH	Credit points
PPM01	Design of Experiments	Design of Experiments & Exercises	1	4	5
PPM02	Data Mining and Statistics	Multivariate Data Analysis (MVA)	1	4	5
PPM03	Process Engineering and Industrial (Bio) Chemistry	Process Engineering and Industrial (Bio) Chemistry	1	4	5
PPM04	Sensors Fundamentals and Applications	Sensors Fundamentals and Applications	1	4	5
PPM05	Specialized Polymer Analytics	Thermal Analysis and Process Safety	1	2	5
		Microscopy and Optics		2	
PPM06	Technology Management	Innovation Management / Quality Management / Project Management	1	4	5
PPM07	Advanced Material Synthesis	Advanced Materials	2	2	5
		Synthetic Materials		2	
PPM08	Polymer Based Materials	Selected Soft Materials	2	2	5
		Product Functionality Design		2	
PPM09	Industrial Process Analytics	Process Analytical Chemistry	2	2	5
		Sampling and sample preparation		2	
PPM10	Industry-Related Topics	Regulatory Affairs	2	2	5
		IP Management		2	
PPM11	Module from other schools or universities	Modules from other schools or universities with at least 4 SWS and 5 ECTS-credits to be approved by examination commission	1 or 2		5
PPM12	Project Oriented Learning	Information Retrieval and Evaluation	2	2	20
		Research Seminar		2	
		Team Project		12	
PPM13	Master's Thesis	Master's Thesis Project and Defense (internal/external)	3	2	30
		Research Seminar to Master's Thesis			
PPM14	Internship semester	Additional Module only for students with 180 ECTS Bachelor's degree	3		30

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Assignment of Marks / Assessment of Quality

Relative ECTS Marks

The international standard foresees that the best 10% of those students who pass receive the mark „A", regardless of which mark they may receive according to the German marking system. With this system, the performance of students who have passed can be compared more objectively, taking into account that different courses may have different degrees of difficulty.

Student performance	ECTS mark
the best 10%	A = excellent
the next 25%	B = very good
the next 30%	C = good
the next 25%	D = satisfactory
the next 10%	E = sufficient
	F = failing

Since a large number of students are necessary in order to correctly calculate the relative ECTS marks, the conventional German marking system (1-5) shall be used and adapted as shown in the table below (valid as of February 2011).

ECTS mark	German mark	ECTS definition	German translation
A	1,0 – 1,3	excellent	hervorragend
B	1,4 – 2,0	very good	sehr gut
C	2,1 – 2,7	good	gut
D	2,8 – 3,5	satisfactory	befriedigend
E	3,6 – 4,0	sufficient	ausreichend
FX/F	4,1 – 5,0	failing	nicht bestanden

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Remarks Concerning the Description of Modules

The module descriptions are meant to offer students information regarding the course of studies, curriculum content, qualitative and quantitative requirements, the relationship of the individual modules to other modules and integration of the module into the general concept of the course of studies. The module descriptions are listed in tabular form.

The following remarks will help the reader to understand the terms used in the module descriptions.

Module description / abbreviation:

A module name and abbreviation have been assigned to every module. The module name provides information about the content of the module. The corresponding abbreviation begins with the first letter of the name of the degree program. It ends with a number of a sequence of numbers. Thus, the abbreviation PPM01 stands for the first module in Polymer & Process Analytical Chemistry.

Courses:

The courses included in a module are listed separately.

Semester:

The semester in which a module is offered is indicated.

Person responsible for the module:

This person is responsible for the editing of the module.

Instructor:

Instructors are responsible for the content and organization of their courses and/or those courses which are held by an associate instructor.

Language:

The language in which the course is taught is indicated.

Integration with other courses of study:

In the event that a module is also offered in other courses of study, this shall be indicated.

Type of instruction/WH:

The type of instruction as well as the weekly hours of instruction are indicated in tabular form. The abbreviations stand for:
Lecture (L)
Exercise (E)
Lab work (LW)
Seminar (S)

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Workload and credit points:
The workload consists of class attendance and study outside of class. The hours of class attendance are calculated by multiplying the WH (à 60 minutes) x 15, which is the normal number of weeks per semester, excluding the exam week.
The calculation of the time needed for study outside of class presupposes that students will require the time represented by the credit points. Each credit point represents 30 hours workload. The total workload is the sum of the workload resulting from class attendance and the workload resulting from study outside of class.

Requirements according to the examination regulations:
Students must have already completed the listed modules in order to participate in the respective module.

Recommended prerequisites:
Course instructors indicate the knowledge and proficiency that students should have in order to participate in and understand the subject matter of a course.

Goals of the module / desired outcome:

The goals of the module define the academic, technical and professional qualifications that should be achieved with this module. The desired outcome describes which knowledge, skills and competences are to be acquired through study. Bloom's taxonomy serves as a tool in formulating learning outcomes statements and facilitate the writing of module descriptions. The particular cognitive levels (competence levels) are indicated with stages K1 up to K6 in the module descriptions. In particular the following levels are used: K1: remembering, K2: understanding, K3: applying, K4: analyzing, K5: evaluating, K6: creating.

Content:
The precise content of the course is described (operative level), with which the desired outcome is to be achieved.

Study and exam requirements:
The type of exam and its duration are indicated.

Media used:
The media (overhead projector, digital projector, flip chart, video, etc.) used in the course are indicated; furthermore, which documents are to be made available to the students when and in which form.

Literature:
A list of literature and, if applicable, information regarding multimedia-supported literature is provided. The literature list includes texts that will prepare students for the upcoming seminar as well as texts to accompany the course work during the semester.

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Module Descriptions

PPM01 – Design of Experiments

<table>
<tr><td>Course of studies</td><td colspan="5">Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Design of Experiment (DoE)</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PPM01</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Design of Experiment, lecture classes
• Design of Experiment, class exercises</td></tr>
<tr><td>Semester</td><td colspan="5">1</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr.-Ing. habil. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Andreas Kandelbauer
Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Language</td><td colspan="5">German with minor parts in English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory</td></tr>
<tr><td rowspan="2">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Design of Experiment</td><td>2</td><td>2</td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Design of Experiment</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Knowledge of statistics and chemometrics</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:
• Students will obtain a profound overview of basic approaches and standard methods of current DoE. (K1)
• Students profoundly understand the applicability and limitations of statistical experimental designs. (K2)
• Students have gained hands-on experience in using commercial software packages for planning, evaluating, and visualizing experiments. (K3)
• Students are able to plan experiments using scientifically sound approaches and conduct statistically correct analyses. (K4)
• Students can select, use and understand mathematical operations for data analysis (inferring statistics, response surface methodology, regression analysis etc.). (K4)
• Students can transform scientific or technical problem in a form suitable for statistical analysis (selection of appropriate factors and response quantities). (K5)</td></tr>
</table>

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	• Students understand, evaluate, summarize, and visualize complex statistical results and can identify experimental key factors. (K6) • Students are able to exploit optimization potential of chemical and technical processes using DoE. (K5) • Students work in a self-organized manner and as a member of a team and do their work target-oriented and systematically. (K6)
Content	**Design of Experiment** The course consists of a lecture and accompanying class exercises. Class examples will, to a large extent, be chosen from lecture contents. • Experimental domain, factor analysis, response surface analysis, orthogonality, general strategies in DoE • Screening- and optimization designs • Setting-up of experimental designs • Visualization and analysis of data from experimental designs • Handling of commercial software packages
Study and exam requirements	Written examination (2h), Homework
Media used	Lecture, script as download, board, projector, handouts
Literature	1. Box EP, Hunter JS, Hunter WG, Statistics for Experimenters. Design, Innovation, and Discovery, 2nd edition, Wiley, 2005 2. Myers RH, Montgomery DC, Response Surface Methodology. Process and Product Optimization Using Designed Experiments, Wiley, 2002 3. Cornell J, Experiments with Mixtures. Designs, Models, and the Analysis of Mixture Data, Wiley, 2002 4. Federer WT, King F, Variations on Split Plot and Split Block Experimental Designs, Wiley, 2007 5. Good PI, Hardin JW, Common Errors in Statistics (and how to avoid them), 2nd edition, Wiley, 2006

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PPM02 – Data Mining and Statistics

<table>
<tr><td>Course of studies</td><td colspan="5">Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Data Mining and Statistics</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PPM02</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Multivariate Data Analysis (MVA)</td></tr>
<tr><td>Semester</td><td colspan="5">1</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Language</td><td colspan="5">German with minor parts in English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Multivariate Data Analysis</td><td>2</td><td>2</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Multivariate Data Analysis</td><td>60</td><td>90</td><td>150</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Basic in Statistics</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module, students are able to:
• understand statistical learning and model selection (K2)
• apply dimension reduction methods (K3)
• evaluate variable selection in building regression models (K5)
• develop linear and non-linear regression methods (K6)
• design new multivariate models for a given data set (K6)</td></tr>
<tr><td>Content</td><td colspan="5">Multivariate Data Analysis (MVA)
• Explorative Data Analysis (EDA)
• Principal Components Analysis
• Statistical Learning and Model Selection
• Linear Regression Methods and Regression Shrinkage Methods
• Modeling Non-linear Relationships
• Support Vector Machines
• Artifical Neuronal Networks
• Hyperspectral Imaging</td></tr>
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Study and exam requirements	Written examination (2h)
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets, software practicals in CIP-pool
Literature	1. Kessler, W.: Multivariate Datenanalyse für die Pharma-, Bio- und Prozessanalytik, Wiley-VCH, 2007 2. Esbensen, Kim H.: Multivariate Data Analysis – in Practice, CAMO Press AS, 2002 3. Rebala, Gopinath, Ajay Ravi, and Sanjay Churiwala. An Introduction to Machine Learning. Springer, 2019. 4. Brereton, R.: Chemometrics, Data Analysis for the Laboratory and Chemical Plant, John Wiley & Sons, 2003

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PPM03 – Process Engineering and Industrial (Bio) Chemistry

<table>
<tr><td>Course of studies</td><td colspan="5">Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Process Engineering and Industrial (Bio) Chemistry</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PPM03</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Process Engineering and Industrial (Bio) Chemistry</td></tr>
<tr><td>Semester</td><td colspan="5">1</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Krastev, Prof. Dr. Kuhn, Prof. Dr. Lorenz, Prof. Dr. Kandelbauer, Prof. Dr. Bell, Prof. Dr. Almeida-Streitwieser</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">mandatory</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Process Engineering and Industrial (Bio) Chemistry</td><td>4</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Process Engineering and Industrial (Bio) Chemistry</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physics, chemistry, mathematics</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:

• Students understand the important fundamentals in chemical engineering. (K2)
• Students understand the importance of mechanical and thermal unit operations. (K2)
• Students apply the mechanical and thermal unit operations, which are important in the assessment of devices or equipment in the process engineering industries. (K4)
• Students discuss important examples of industrial chemical and bio chemical plants. (K4)
• Students apply principles of reaction safety in calculations for technical processes. (K3)
• Students understand the importance of membrane technology in chemical engineering and govern methods based on it. (K4)</td></tr>
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	• Students understand the principles and different aspects of polymer engineering processes. (K2) • Students understand the principles and different aspects of biotechnological processes. (K2) • Students understand the principles and different aspects of downstream processes. (K2) • Students interpret such technical systems in the students' future careers or virtually understand, operate and master complete processes based on the acquired knowledge. (K5) • Students assess critically conventional solutions, to improve or to replace them with new solutions. (K4) • Students have developed and strengthened their team and communication skills. (K4)
Content	1. **Practical fundamentals in process engineering (n.n.) / 6 blocks á 90 Min.** a. Definition of process engineering b. Similarities and differences of processes (example: cement production and reforming process) c. Definition of unit operations d. Flow diagrams as the important communication tool in process engineering e. Discussion of practical Examples of characteristic industrial processes by means of Worksheets (e.g. PVC production) 2. **Thermal Reaction Safety (Kandelbauer) / 4 blocks á 90 Min.** a. Thermal Reaction Safety b. Technical Aspects of Reactor Safety c. Assessment of Thermal Process Safety d. Selected Inorganic Technological Processes (optional) 3. **Membrane Technology in Chemical Engineering (Bell) / 2 blocks á 90 Min.** a. Introduction to Membrane Technology b. Applications c. Separation Mechanism d. Membrane Structures e. Membrane Preparation f. Membrane Processes g. Membrane Modules h. Applications, Segments and Markets i. Membranes for Medical Applications 4. **Polymer Engineering (Lorenz) / 6 blocks á 90 Min.** a. Polymer Melts b. Extrusion c. Molding Processes

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	d. Production of sheets and films e. Fibres and Filaments **5. Biotechnology and bioprocess engineering (Krastev) / 6 blocks á 90 min.** a. Biotechnology b. Bio catalytic process engineering c. Bio catalytic processes - examples **6. Downstream Processing (Kuhn) / 6 blocks á 90 Min.** a. Preparative chromatography b. Extraction (liquid-liquid E.; supercritical fluid E.; solid-phase E.) c. Analytical and preparative centrifugation
Study and exam requirements	Written examination (2h)
Media used	Lecture, board, digital projector, handouts
Literature	1. Jess, Andreas; Wasserscheid, Peter: Chemical Technology, An Integral Textbook, Wiley-VCH (2013) 2. McCabe, Warren L.; Smith, Julian C.; Harriott, Peter: Unit Operations of Chemical Engineering, International Edition, McGraw-Hill Higher Education, 7th ed. (2005) 3. Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2. ed. (2012) 4. Katoh, Shigeo; Horiuchi, Jun-ichi; Yoshida, Fumitake: Biochemical Engineering, A Textbook for Engineers, Chemists and Biologists, Wiley-VCH, 2nd, rev. and enl. ed. (2015) 5. Script Polymer Engineering; download Relax platform 6. Natti S. Rao, Basic Polymer Engineering Data, Carl Hanser Verlag, Munich 2017. 7. Callister, W.D., Materials Science and Engineering, An Introduction, 7th edition, John Wiley & Sons (New York), 2007. 8. Groover M.P., Fundamentals of Modern Manufacturing, 4th edition, John Wiley & Sons (New York), 2010. 9. Thomas, S., Weimin, Y. eds., Advances in Polymer Processing, Woodhead Publishing Limited (Cambridge) 2009. 10. Tadmor, Z., Gogos, C.G., Principles of Polymer Processing, John Wiley & Sons, (Hoboken, New Jersey) 2006.

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PPM04 – Sensors Fundamentals and Application

<table>
<tr><td>Course of studies</td><td>Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td>Sensor Fundamentals and Applications</td></tr>
<tr><td>Abbreviation</td><td>PPM04</td></tr>
<tr><td>Course(s)</td><td>• Sensor Fundamentals and Applications</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Instructor</td><td>Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Language</td><td>German</td></tr>
<tr><td>Status within the curriculum</td><td>elective</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Design of Experiment</td><td>2</td><td>1</td><td>1</td><td></td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Sensor Fundamentals and Applications</td><td>45</td><td>105</td><td>150</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>45</td><td>105</td><td>150</td><td>5</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>none</td></tr>
<tr><td>Recommended knowledge / course work</td><td>Knowledge of physics, physical chemistry, instrumental analytics</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module students can ...

• ... overview the basic electrical and optical measuring methods as well as signal processing approaches. (K1)
• ... understand the functional principles, designs and performance factors of physical and bio/chemical sensors. (K2)
• ... analyze and perform concrete measuring tasks including designing and building simple customized sensors. (K4)
• ... select, put into operation, implement and operate commercial sensors and sensor systems in laboratory and production contexts. (K5)
• ... structure and execute adequate basic post-acquisition signal processing and data evaluation. (K4)
• ... work in a systematic, self-organized and target-oriented manner, alone as well as part of a team. (K6)</td></tr>
<tr><td>Content</td><td>The course consists of lectures and accompanying class exercises as well as practicals, all treating:

• Basic concepts of sensor technology, actor technology, signal processing and evaluation</td></tr>
</table>

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	• Working principles, designs and components of physical, chemical and biochemical sensors • Application of such sensors to specific measuring tasks
Study and exam requirements	Written examination (2h) and term paper (submitting solutions to given theoretical and/or practical problem/s), term paper contributes at most 30% to overall module grade, depending on extent and degree of difficulty
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets
Literature	1. Gründler, P.: Chemical Sensors, Springer, 2007 2. Hauptmann, P.: Sensors: Principles and Applications, Prentice-Hall, 1993 3. Eggins, B. R.: Chemical Sensors and Biosensors, John Wiley & Sons, 2004 4. Niebuhr, J., Lindner G.: Physikalische Messtechnik mit Sensoren, Oldenbourg Verlag, München, 2011 5. Freudenberger, A.: Prozessmesstechnik, Vogel Verlag, Würzburg, 2000.

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PPM05 – Specialized polymer analytics

Course of studies	Polymer & Process Analytical Chemistry (MSc)
Module	**Specialized polymer analytics**
Abbreviation	PPM05
Course(s)	• Thermal Analysis and Process Safety • Microscopy and Optics
Semester	1
Person responsible for the module	Prof. Dr. Andreas Kandelbauer
Instructor	Prof. Dr. Andreas Kandelbauer Prof. Dr. Marc Brecht
Language	German with minor parts in English
Status within the curriculum	elective
Type of course / WH	see table below
Workload in hours	see table below
Credit points	5
Prerequisites for attending this course	none
Recommended knowledge / course work	Physics, chemistry, mathematics
Module goals / desired outcome	After successful completion of this module: • Students understand principles and theory of thermal analytical methods such as Differential Scanning Calorimetry (DSC), Thermogravimetry (TGA), Dynamic Mechanical Analysis (DMA), Rheology, Reaction Calorimetry (RC) and other calorimetric methods. (K2) • Students understand the determination of basic characteristic values of material constants (melting points, glass transition temperatures, reaction enthalpies, etc.). (K2) • Students derive complex information from calorimetric and rheometric measurements (reaction kinetics, activation energy barriers, thermal stability parameters, etc.). (K3) • Students derive relevant data in the context of thermal process safety. (K3)

Type of course / WH:

Course	L	E	LW	S
Thermal Analysis and Process Safety	2			
Microscopy and Optics	2			

Workload in hours:

Course	Class attendance	Study outside of class	Total	CP
Thermal Analysis and Process Safety	30	45	75	
Microscopy and Optics	30	45	75	
Total	**60**	**90**	**150**	**5**

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	• Students derive and predict technologically important information regarding process windows, process optimization and process safety. (K4) • Students set-up complex experiments in order to study the physical / chemical systems (guidelines for thermal and rheological analysis). (K5) • Students apply specialized data treatment methods. (3) • Students apply mathematical methods for Data treatment (kinetic modelling). (K3) • Students apply commercial software packages. (K3) • Students select appropriate thermal and rheological analysis protocols depending on the problem. (K3) • Students critically examine experimental results. (K4) • Students correctly apply thermal and rheological material data and application of these data for process understanding and optimization. (K4) • Students interpret such technical systems in the students' future careers or to virtually understand, operate and master complete processes based on the acquired knowledge. (K5) • Students assess critically conventional solutions to improve or to replace them with new solutions. (K6) • Students have a detailed knowledge of geometrical and ray optics (K1) • Students understand the formation of images by mirrors and lenses (K2) • Students understand the difference between geometrical and wave optics (K2) • Students are able to solve problems of intermediate complexity (K3) • Students are able to construct images formed by a simple lens system (e.g. a microscope) (K3) • Students have a profound knowledge of the most relevant microscopic techniques (K1) • Students are able to assign a problem to the most relevant microscopy techniques (K4) • Students are able to analyze a given microscopy technique and find out the most relevant relations (K4) • Students create and give an oral presentation about a microscopic technique for other students (K6)
Content	1. Thermal Analysis and Process Safety • Basics and application of standard and advanced thermal analytical and calorimetric methods in the laboratory • Principles and experimental set-ups of different kinds of calorimetry • Judgement of the advantages and disadvantages, application fields and limits of the various thermal analytical methods

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	• Reaction calorimetry / microcalorimetry, Application of real-time temperature / heat-flow measurements in chemical reactions • Classic and advanced means of data treatment (e.g., model-based and model-free kinetic data analysis) • Prerequisites for obtaining good data • Derivation of quality relevant characteristic data • Use of thermal data in the risk assessment of thermally stimulated physical/chemical processes 2. Microscopy and Optics Optical technologies are a cornerstone of all analytical technologies. The lecture starts with a short repetition of geometric optics. We will discuss wave optics in free space and waveguides, followed by the basic function of lasers including modes in optical resonators and Fourier transformations in the description of optical setups. Then we will consider aberrations of optical elements, lens design and technical optics. In the second part we will focus on microscopy, we will discuss the resolution of a conventional microscope as well as methods of resolution improvement like structured illumination, 4Pi, STED, STROM and FLIM microscopy and single-molecule sensitive detection. In all parts examples for applications will be given.
Study and exam requirements	Written examination (2h), Presentation
Media used	Lecture, board, digital projector, handouts
Literature	1. Ehrenstein GW, Riedel G, Trawiel, Thermal Analysis of Plastics: Theory and Practice, Hanser, 2004 2. Frick A, Stern C, DSC-Prüfung in der Anwendung, Hanser, 2013 3. Sarge SM, Höhne GWH, Hemminger W, Calorimetry. Fundamentals, Instrumentation, and Applications, Wiley, 2014 4. Stoessel F, Thermal Safety of Chemical Processes. Risk Assessment and Process Design, Wiley, 2008 5. Vyazovkin S, Isoconversional Kinetics of Thermally Stimulated Processes, Springer, 2015 6. Wissenschaftliche Originalliteratur (Aufgaben-bezogene Artikel aus peer-reviewed Zeitschriften) 7. Brummer R, Rheology Esseentials of Cosmetic and Food Emulsions, Springer Berlin, 2005 8. Mezger Th, The Rheology Handbook, Vincentz, 2006 9. Schramm G, Einführung in die Rheologie und Rheometrie, Gebr. Haake, Karlsruhe 10. Hecht, E.: Optics, Addison-Wesley, 2001 11. Demtröder, W.: Laser spectroscopy I & II, Springer; 5th ed. 2014

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	12. Murphy, D.B.: Fundamentals of Light Microscopy and Electronic Imaging, Wiley-Blackwell; 2nd ed. 2012 13. Scientific publications

PPM06 – Technology Management

<table>
<tr><td>Course of studies</td><td>Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td>Technology Management</td></tr>
<tr><td>Abbreviation</td><td>PPM06</td></tr>
<tr><td>Course(s)</td><td>Quality Management
Innovation Management
Project management</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Alexander Schuhmacher</td></tr>
<tr><td>Instructor</td><td>Prof. Dr. Alexander Schuhmacher</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Status within the curriculum</td><td>elective</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Innovation and Project Management</td><td>3</td><td></td><td></td><td></td></tr>
<tr><td>Quality Management</td><td>1</td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Innovation and Project Management</td><td>45</td><td>45</td><td>90</td><td></td></tr>
<tr><td>Quality Management</td><td>15</td><td>45</td><td>60</td><td></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>none</td></tr>
<tr><td>Recommended knowledge / course work</td><td>Basics understanding of project management principles, no further special prerequisites</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module:
Students understand basic principles of innovation strategies and innovation processes. (K2)
Students understand how to establish and implement a functional quality management-, quality control- and risk management-procedure/system in the life cycle of a regulated product (K3)
Students have a profound understanding of quality control and quality assurance systems
Students understand the significance of the context of R&D strategy for the daily business of researchers in an R&D organization. (K2)
Students are able to evaluate how projects are managed efficiently and effectively. (K5)
Students have a good understanding of project life-cycle-management principles. (K3)</td></tr>
</table>

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	• Students are able to analyze the responsibilities and tasks of QM in daily business. (K4) • Students are able to adhere to quality and regulatory standards
Content	Innovation and Project Management • Economic relevance of innovation • Innovation strategies • Innovation processes • R&D management • Open innovation • Portfolio management • Product life-cycle-management • Case-in-points Quality Management • Quality management, Risk analysis/management and GLP/GMP-regulations • Basic principles of quality control and quality assurance • Quality management systems • Case-in-points
Study and exam requirements	Written examination (2h)
Media used	Lecture, group work, interactive discussions, board, digital projector, handouts, team works and case studies
Literature	1. O. Gassmann, A. Schuhmacher, M. von Zedtwitz, G. Repmeyer (2018) Leading Pharmaceutical Innovation. How to Win the Life Science Race. Springer Verlag 2. Schein EH (1997) Organizational Culture and Leadership. Jossey-Bass Publishers 3. S. Nokes and S. Kelly. Guide to Project Management. FT Press (2003) 4. L. Brown and T. Grundy (2011) Project Management for the Pharmaceutical Industry. Gower Publishing Company 5. R.D. Austin (2004) Managing projects large and small. Harvard Business Essentials 6. PMI (2008) The Standard for Portfolio Management. 2nd edition. Project Management Institute 7. A. Schuhmacher, M. Hinder, O. Gassmann (2016) Value Creation in the Pharmaceutical Industry: The Critical Path Towards Innovation, Wiley International 8. ISO 9000, ISO 9001:2015, ISO 13485,

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PPM07 – Advanced Material Synthesis

Course of studies	Polymer & Process Analytical Chemistry (MSc)
Module	**Advanced Material Synthesis**
Abbreviation	PPM07
Course(s)	• Advanced Materials • Synthetic Materials / Synthetische Materialien
Semester	2
Person responsible for the module	Prof. Dr. habil. Andreas Kandelbauer
Instructor	Prof. Dr. habil. Andreas Kandelbauer (Advanced Materials) Lehrbeauftragter Dr. Michael Walz (Synthetic Materials)
Language	German with minor parts in English
Status within the curriculum	mandatory

Type of course / WH

Course	L	E	LW	S
Advanced Materials	2			
Synthetic Materials	2			

Workload in hours

Course	Class attendance	Study outside of class	Total	CP
Advanced Materials	30	45	75	
Synthetic Materials	30	45	75	
Total	**60**	**90**	**150**	**5**

Credit points	5
Prerequisites for attending this course	none
Recommended knowledge / course work	Physik, Chemie, Mathematik
Module goals / desired outcome	Nach erfolgreichem Abschluss dieses Moduls können die Studierenden: • … über ein vertieftes Grundlagenwissen ausgewählter materialwissenschaftlicher Inhalte mit Schwerpunkt auf Struktur-Funktionalitätsbeziehungen verfügen. (K1) • … anwendungsorientierte Fragestellungen der wechselseitigen Abhängigkeit zwischen Materialfunktionalität und Produkteigenschaften diskutieren. (K3) • … moderne Syntheseverfahren für polymerbasierte Hochleistungs(verbund)werkstoffe verstehen, einordnen und kritisch diskutieren. (K3) • … unterschiedliche chemische und physikalische Funktionalisierungsstrategien für funktionelle Oberflächen beschreiben, bewerten und kritisch diskutieren. (K3) • … chemische Lösungsstrategien für materialwissenschaftliche Fragestellungen entwickeln und chemische Verfahren u. Stoffklassen auf neue Funktionalitätsanforderungen adaptieren. (K3)

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	• … die Eigenschaften und Strukturen von Hochleistungspolymeren und deren Anwendungen verstehen. (K2) • … die Architekturen und den Chemismus verschiedener Nanomaterialien, Hochleistungspolymere und Polymerverbundwerkstoffe verstehen und diskutieren. (K3) • … die speziellen Strategien zur Performanceverbesserung von Werkstoffen verstehen und diskutieren. (K3) • … die Prinzipien der Verbundwerkstofftechnologie, Herstellungs- und Verarbeitungsverfahren verstehen und auf ein spezielles Werkstoffanwendungsprofil anwenden. (K2) • … über Methodenkompetenz für eine funktionsgerechte, designorientierte Grundstoffauswahl und ein materialgerechtes Synthesedesign verfügen. (K3) • … über Problemlösungskompetenz zur Formulierung eines Prozessdesigns verfügen. (K3) • … materialwissenschaftliche Aspekte von Relevanz für Anwendung und F&E in Polymerindustrie, Medizinprodukte-Industrie und Werkstoffentwicklung verstehen. (K2) • … die Zusammenhänge zwischen Reaktionsbedingungen, Prozessparametern und Verfahrensmerkmalen, mikroskopischen Eigenschaften, chemischen Eigenschaften und technologischen Materialeigenschaften verstehen und analysieren. (K4) • … die Kompatibilität zwischen verschiedenen Materialien (organisch, polymer, elastomer, anorganisch, metallisch) verstehen, bewerten und konkrete Verfahrensstrategien zur Verbesserung der Kompatibilität entwickeln. (K5)
Content	1. Advanced Materials • Hochleistungsfasern • Hochleistungspolymere • Hochleistungsverbundwerkstoffe • Biobasierte Materialien • Nanomaterialien u. a. „Emerging Technologies“ • Spezielle Funktionalitäten: Selbstheilung, interaktive („stimulus-responsive“) Materialien, „smarte“ Materialien • Herstellung und Verarbeitung von Verbundwerkstoffen (SMC, BMC, Pultrusion, RIM, RTM, etc.) • Spezielle und aktuelle Themen anhand konkreter wissenschaftlicher Originalliteratur • Synthetic Materials • Aufbau und Design hierarchischer Strukturen • Partikelsynthese (wie Polymerpartikel, Silica-Partikel, hohle Microsphären, Hybridpartikel, …) • Chemische Strategien zur Oberflächenfunktionalisierung von Hochleistungswerkstoffen • Synthese von anorganisch-organischen Hybridmaterialien • Poren-Design in Festkörpern (Aerogele, Schäume, innere Oberflächen von Partikeln u.a.)

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	• Kompatibilisierung von Materialien für Advanced Composites und Nano-Composites • Spezielle Herstellungsverfahren (3D-Druck / additive Manufacturing, reaktive Extrusion, u. a.) • Spezielle chemische Syntheseverfahren (Templat-gestützte Synthesen, Layer-by-Layer Abscheidung, Sol-Gel-Synthesen u. a.) • Spezielle chemische Prozesstechnik unter Berücksichtigung von Ansätzen zur Prozessintensivierung (Flow Chemistry / Mikroreaktionstechnik, reaktive Destillation, rotating disk reactors, katalytische Verfahren, Anwendung von White Biotechology, u. a.) • Nutzung biogener Rohstoffe in der Synthese von Hochleistungsmaterialien • Spezielle und aktuelle Themen anhand konkreter wissenschaftlicher Originalliteratur
Study and exam requirements	Klausur 2h (85%), Hausarbeit mit Präsentation zum Bereich Advanced Materials (15%)
Media used	PPT, Tafelanschrieb, Overhead-Folien, Skriptum, Tischvorlagen, Formelsammlungen, Video-Tutorials, Übungen
Literature	1. Ullmann´s Encyclopedia of Industrial Chemistry, Wiley 2012 2. Ghosh SK, Self-Healing Materials, Wiley, 2012 3. Krueger A, Carbon Materials and Nanotechnology, Wiley, 2012 4. Dodiuk H, Goodman S, Handbook of Thermosetting Plastics, CRC / Elsevier, 2014 (3rd ed.) & 2021 (4th ed.) 5. Kumar C, Nanomaterials for the Life Sciences (Series) Vols. 1-10, Wiley, 2012 6. Kickelbick G, Hybrid Materials, Wiley-VCH, 2008 7. Aktuelle wissenschaftliche Review-Artikel und Originalarbeiten in wissenschaftlichen Fachzeitschriften (z. B. Review Articles der Zeitschrift Advanced Materials und verwandter Zeitschriften; Originalarbeiten aus Journal of Applied Polymer Sciences, Polymers, Advanced Materials u. anderen Zeitschriften)

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PPM08 – Polymer Based Materials

<table>
<tr><td>Course of studies</td><td colspan="5">Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Polymerbasierte Materialien</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PPM08</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Polymere / Selected Soft Materials
• Product Functionality Design</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Language</td><td colspan="5">German (class language speaking), English (documents)</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">elective</td></tr>
<tr><td rowspan="4">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Polymere</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Product Functionality Design</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="5">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Polymere</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Product Functionality Design</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physik, Chemie, Mathematik</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">Nach erfolgreicher Teilnahme an diesem Modul können die Studierenden…

• verstehen, wie makroskopische Eigenschaften von mikroskopischen Eigenschaften abhängen. (K2)
• über wissenschaftliche Literatur und Datenbanken relevante Materialien für bestimmte Anwendungen / Eigenschaftsprofile ausforschen. (K4)
• analytisch-systematisch komplexe Materialsysteme anhand von Material- und Produktlastenheften suchen und auswählen. (K4)
• die Eigenschaften, Ordnungszustände, Strukturbildung und Phasenübergänge verschiedener Arten weicher Materie verstehen. (K2)
• die Zusammenhänge zwischen mikroskopischen Eigenschaften, mesoskopischer Ordnung und makroskopischen Materialeigenschaften mit</td></tr>
</table>

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	Schwerpunkt auf Struktur-Funktionalitätsbeziehungen und Grenzflächen verstehen und analysieren. (K4) • die Kompatibilität zwischen verschiedenen Materialien verstehen, bewerten und Voraussagen hierzu entwickeln. (K5) • ... den Umgang mit Software zur Materialauswahl, Eigenschaftsvorhersage und Produktentwicklung beherrschen. (K4) • ... funktionale Materialkonzepte von der Modellbildung bis zum Produkt umsetzen. (K5) • ... die Anwendungsbreite und Limitation bestehender Materialien und Technologien benennen. (K4) • ... über Zusammenhangswissen zur Lösung materialwissenschaftlicher Problemstellungen verfügen. (K3) • ... Materialien unter technologischen und Designgesichtspunkten auswählen. (K4)
Content	1. Polymere • Kräfte, Energien, Zeit- und Längenskalen in polymerer und flüssigkristalliner Materie verschiedener Phasen • Stabilität, Phasenverhalten, Ordnungszustände, Selbstorganisationsphänomene, Rolle von Ober- und Grenzflächeneffekten • Eigenschaften von Polymeren in Lösung, Schmelze, flüssigkristallinen Zuständen, Kristall und Festkörper 2. Product Functionality Design • Allgemeine Prinzipien der mathematisch-physikalischen Modellbildung anhand konkreter technischer Fragestellungen • Methoden der systematischen Materialauswahl • Grundlegende Konzepte der ökologischen und nachhaltigen Produktion • Abstimmung von Design und Material zur Optimierung von Gebrauchseigenschaften • Verfahren zur Beschleunigung des Designprozesses
Study and exam requirements	Klausur 2h und Hausarbeit (Beitrag der Hausarbeit zur Modulnote maximal 20%, abhängig von Umfang und Schwierigkeitsgrad)
Media used	Tafelanschrieb, Overheads, Skriptum, Tischvorlagen
Literature	1. Stokes RJ, Evans DF, Fundamentals of Interfacial Engineering, Wiley-VCH, 1997 2. Gedde, UW, Polymer Physics, Kluwer Academic Publishers, 2001 3. Jones, R. A. L.: Soft Condensed Matter, Oxford University Press, 2002 4. Hamley, I, Introduction to Soft Matter. Synthetic and Biological Self-assembling Materials, Wiley, 2000Methodik

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	der Werkstoffauswahl: Der systematische Weg zum richtigen Material, Carl Hanser Verlag GmbH & Co. KG; Auflage: 1 (2006), ISBN-10: 9783446406803 5. van Krevelen, D.W.; te Nijenhuis K., Properties of polymers. Their correlation with chemical structure, their numerical estimation and prediction from additive group contributions, 4th ed., Elsevier: Amsterdam, The Netherlands, 2009. 6. Nash WA, Schaum's Outline of Strength of Materials (Schaum's Outlines) 432 Seiten, Schaum Outline Series; Auflage: 4 Sub (1998) Englisch, ISBN-13: 978-0070466173 7. Software: CES Edu Pack 2013, Grantadesign, Cambridge

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<table>
<tr><td>Course of studies</td><td colspan="5">Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Industrial Process Analytics</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PPM09</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Process Analytical Chemistry
• Sampling and Sample Preparation</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Language</td><td colspan="5">German with minor parts in English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">elective</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Process Analytical Chemistry</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Sampling and Sample Preparation</td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td rowspan="5">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Process Analytical Chemistry</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Sampling and Sample Preparation</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Knowledge of instrumental analysis</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module, students are able to:
• explain theoretical and instrumental concepts of process analyzers (K2).
• apply process spectroscopic methods for different industry branches and requirements (K3).
• compare the application of process analyzers in combination with microfluidic systems for medical and biomedical sensing and manipulation (K4)
• evaluate analyzer benefits and the trade-off between initial capital costs and ongoing cost-of ownership (K5)
• differentiate on-line, in-line, at-line and off-line methods including sampling strategies and control technologies (K4).
• evaluate time delay effects in process segments of sample transport lines (K5).
• evaluate existing or proposed locations for the sampling nozzle and make a decision (K5).</td></tr>
</table>

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	• design process analyzer systems for monitoring and control of productions plants (K6).
Content	Process Analytical Chemistry: • Understanding processes and how to improve them • Optofluidic System Technology • Implementation of Process Analytical Technologies • UV-Visible Spectroscopy for On-line Analysis • Vibrational Spectroscopy for Process Analytical Applications • Process Mass Spectrometry Sampling and Sample Preparation • Measurement Process and Errors in Quantitative Analysis • Method Performance and Method Validation • Location and Design of Process Sampling Taps • Preconditioning the Process Sample • Sample Conditioning and Disposal • Sample Isolation and Switching Systems
Study and exam requirements	Written examination (2h)
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets
Literature	1. Rabus, Rebner, Sada: Optofluidics, Process Analytical Technology, De Gruyter, 2018 2. Kessler RW (Ed.): Prozessanalytik Strategien und Fallbeispiele aus der industriellen Praxis, Wiley-VCH, 2006 3. Bakeev: Process Analytical Technology: Spectroscopic Tools and Implementation Strategies for the Chemical and Pharmaceutical Industries, Wily-VCH, 2010. 4. Undey, Low, Menezes, Koch: PAT Applied in Biopharmaceutical Process Development and Manufacturing, CRC Press 2012 5. Tony Waters, Industrial Sampling Systems, 2014, Swagelok 6. Cazes, Analytical Instrumentation Handbook, CRC Press, 2012 7. John Kenkel, Analytical Technics for Technicians, CRC Press, 2003

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PPM10 – Industry-Related Topics (Regulatory Affairs, IP Management)

<table>
<tr><td>Course of studies</td><td colspan="5">Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Industry-Related Topics</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PPM10</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Regulatory Affairs
• IP Management</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Alexander Schuhmacher</td></tr>
<tr><td>Instructor</td><td colspan="5">Dr. Xin Xiong
Prof. Dr. Alexander Schuhmacher</td></tr>
<tr><td>Language</td><td colspan="5">German with minor parts in English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">elective</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td></td><td></td></tr>
<tr><td>Regulatory Affairs</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>IP Management</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Regulatory Affairs</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>IP Management</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Sum</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">No specific knowledge required</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:
• Students understand the strategic and operational relevance of regulatory affairs and intellectual property (IP) rights for high-tech industries, such as the pharmaceutical, biotechnology and medical device industries. (K2)
• Students understand the specific formalities in the development and manufacturing of medical devices and pharmaceutical products – with a focus of the respective national and international registration and authorization rules. (K2)
• Students are able to roughly evaluate a product and the manufacturing process based on the relevant national/international laws/directives/regulations and standards (K2)
• Students understand the international and European patent laws, patentability requirements, how to file a patent application and the writing of patent claims. (K2)
• Students understand the basic principles of the German “Arbeitnehmererfindergesetz”</td></tr>
<tr><td>Content:</td><td colspan="5">Regulatory affairs
• Medical device approval in EU, US and Germany
• Medicinal product/ pharmaceutical products approval in EU, USA and Germany</td></tr>
</table>

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	• National and centralized registration of drugs in EU • Directives, regulations and guidance • Classification of the regulated products • Technical route for approval of medical devices in EU • ICH and harmonization of standards, guidance and directives IP Management • European Patent Convention and Patent Cooperation Treaty • Filing a patent application • Searching for patents • Patentability analysis • Writing patent claims • Arbeitnehmererfindergesetz
Study and exam requirements	Written examination (2h), presentation
Media used	Lecture, group work, interactive discussions, handouts, flip charts
Literature	1. The European Patent Convention (http://documents.epo.org/projects/babylon/eponet.nsf/0/00E0CD7FD461C0D5C1257C060050C376/$File/EPC_15th_edition_2013_de_bookmarks.pdf) 2. FDA-approvals: FDA regulated products https://www.fda.gov/NewsEvents/ProductsApprovals/ 3. EMA- EU authorization of medicines http://www.ema.europa.eu/ema/index.jsp?curl=pages/about_us/general/general_content_000109.jsp 4. EU Guidance for approval of medical devices https://ec.europa.eu/growth/sectors/medical-devices/guidance_nl

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PPM11 – Module from other schools or universities

Course of studies	Polymer & Process Analytical Chemistry (MSc)					
Module	**Module from other schools or universities**					
Abbreviation	PPM11					
Course(s)	Modules from other schools or universities with at least 4 SWS and 5 ECTS-credits to be approved by examination commission					
Semester	1 or 2					
Person responsible for the module	Prof. Dr. Andreas Kandelbauer					
Instructor						
Language	English or German					
Status within the curriculum	Elective					
Type of course / WH	Course	L	E	LW	S	
	Internship semester	-	-	-	-	
Workload in hours	Course	Class attendance	Study outside of class	Total	CP	
	Module from other schools or universities	60	90	150	5	
	Total		**90**	**150**	**5**	
Credit points	5					
Prerequisites for attending this course	After approval by the Examination Board An elective module may be selected from the offer of other faculties, colleges or universities.					
Recommended knowledge / course work						
Module goals / desired outcome	depending on the selected module					
Content	depending on the selected module					
Study and exam requirements	depending on the selected module					
Media used	depending on the selected module					
Literature	depending on the selected module					

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PPM12 – Project Oriented Learning

Course of studies	Polymer & Process Analytical Chemistry (MSc)
Module	**Project Oriented Learning**
Abbreviation	PPM12
Course(s)	• Information Retrieval and Evaluation • Research Seminar • Team Project
Semester	1
Person responsible for the module	Prof. Dr. Andreas Kandelbauer
Instructor	Prof. Dr. Kandelbauer, Prof. Dr. Rebner, Prof. Dr. Lehnert, Prof. Dr. Lorenz, Prof. Dr. Brecht, Prof. Dr. Carl-Martin Bell
Language	German, English
Status within the curriculum	Mandatory
Type of course / WH	<table><tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr><tr><td>Information Retrieval and Evaluation</td><td></td><td></td><td></td><td>2</td></tr><tr><td>Research Seminar</td><td></td><td></td><td></td><td>2</td></tr><tr><td>Team Project</td><td></td><td></td><td>12</td><td></td></tr></table>
Workload in hours	<table><tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr><tr><td>Information Retrieval and Evaluation</td><td>30</td><td>45</td><td>75</td><td></td></tr><tr><td>Research Seminar</td><td>30</td><td>45</td><td>75</td><td></td></tr><tr><td>Team Project</td><td>180</td><td>270</td><td>450</td><td></td></tr><tr><td>Total</td><td>240</td><td>360</td><td>600</td><td>20</td></tr></table>
Credit points	20
Prerequisites for attending this course	For reasons of occupational safety, the students have to prepare the theoretical and practical contents of the module prior to starting practical work in the laboratory. Proof of this is provided by successful participation in a safety and / or introductory colloquium (written or oral).
Recommended knowledge / course work	Physics, chemistry, mathematics
Module goals / desired outcome	Objective is the education of the students in setting-up, planning and performing a project aiming at the solution of a specific research question. After successful completion of this module students: • understand how search engines and citation management programs function and can be used (K2). • use relevant literature data bases with respect to scientific publications, patents, reviews, and monographs (K3). • conduct systematic and efficient scientific literature searches (source identification and exploitation) (K3).

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	• cite and organize literature correctly according to respective scientific standards and to save citations using citation managers (K4) • evaluate and efficiently document relevant publications and text/content therein (K5). • can define a research project: how to structure complex scientific questions and break them down into single steps like formulating state of the art and formulating scientific hypotheses. (K6) • successfully apply tools for practical project planning and coordination (Gantt-diagrams, decision gates, milestones, deliverables, etc.). (K5) • professionally apply tools for practical project management (action items, meeting organization, work documentation, efficient use of resources, coordination, etc.). (K4) • effectively extract information from technical and scientific databases and evaluate it with regard to a specific research question. (K4) • gain in-depth knowledge about a specific topic depending on the specified research question. (K3) • select the appropriate scientific methodology depending on the specific research question. (K4) • are able to think conceptually, work beneficial together in project teams and have developed and strengthened their team and communication skills. (K5) • properly present and scientifically sound defense their own findings in front of a panel of experts (= council of supervisors) (K5) • discuss competently experimental results in the light of the state of the art and comparing own findings to the scientific literature. (K4) • assimilate to novel research questions, adapt to / orientate in a new field. (K5) • are able to work in a self-organized manner and as a member of a team and do their work target-oriented and systematically. (K6)
Content	Information Retrieval and Evaluation • Reference data bases, search engines, citation managers • Literature search examples/exercises based on concrete scientific questions The students will work in teams of 3 to 4 people on a defined research question. The research question is defined by the supervisor at the faculty and will be in accordance with current research activities at the department. The students will prepare a scientific and technological state of the art on this research question and based on this they will define a project plan addressing all relevant issues of a real research project (time schedule, resource plan, objectives, means to arrive at the

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	objectives, required methods, hypotheses, etc.). This project plan will be disseminated as a formal project application with a special focus on a comprehensive state of the art. No single-person projects are admissible and all projects are hosted by the faculty exclusively. The actual research project plan set up by the students will then be realized. The students will perform the necessary scientific and technological experiments based on the state of the art on this research question and their research proposal. The students organize their project by themselves and are guided by the supervising professor. The project results will be disseminated as a formal final project report. The results will also be presented at a final oral defense in front of a panel of all supervising professors and a poster presentation will be prepared.
Study and exam requirements	Study requirements: oral presentation of project plan during semester Exam requirements: Written seminar paper (= state of the art) (50%) Final project report (35%) Final project defense (15%), including oral presentation and poster presentation
Media used	Lecture, board, digital projector, handouts
Literature	1. Chalmers AF (2007) Wege der Wissenschaft. Einführung in die Wissenschaftstheorie, 6. Auflage, Nachdruck, Springer 2. Patzak G, Rattay G (2004) Projektmanagement, 4. Auflage, Linde International 3. Baguley P (1999) Optimales Projektmanagement, Falken 4. Scientific Original papers, depending on the specific research question 5. H.F. Ebel et al. (2006) Schreiben und Publizieren in den Naturwissenschaften, Wiley-VCH Weinheim.

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PPM13 – Master’s Thesis

<table>
<tr><td>Course of studies</td><td>Polymer & Process Analytical Chemistry (MSc)</td></tr>
<tr><td>Module</td><td>Master’s Thesis</td></tr>
<tr><td>Abbreviation</td><td>PPM13</td></tr>
<tr><td>Course(s)</td><td>Master Thesis Project and Defense
Research Seminar to Master’s Thesis</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td>All instructors of faculty</td></tr>
<tr><td>Language</td><td>English or German</td></tr>
<tr><td>Status within the curriculum</td><td>Mandatory</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Master’s Thesis</td><td>-</td><td>-</td><td></td><td>-</td></tr>
<tr><td>Seminar</td><td>-</td><td>-</td><td>-</td><td>2</td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Master Thesis</td><td></td><td>840</td><td>840</td><td>28</td></tr>
<tr><td>Seminar</td><td>30</td><td>30</td><td>60</td><td>2</td></tr>
<tr><td>Total</td><td>30</td><td>870</td><td>900</td><td>30</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>30</td></tr>
<tr><td>Prerequisites for attending this course</td><td>The master's thesis module may only be started if at least 45 ECTS credits have been earned from the modules of semesters 1 and 2. The modules PPM01, PPM02, PPM03, PPM07, PPM12 and possibly PPM14 must be completed.</td></tr>
<tr><td>Recommended knowledge / course work</td><td>Successful completion of research project</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module:
Students perform detailed and in-depth research on a defined scientific field of study. (K6)
Students work independently in a team on a defined research project. (K4)
Students evaluate and implement insights / findings of scientific literature. (K5)
Students prepare and present scientific results. (K3)
Students apply modern adequate strategies for finding scientific solutions. (K4)
Students promote team work in a research group. (K4)</td></tr>
<tr><td>Content</td><td>Students will work independently on a defined research project in a research group at the Reutlingen University or at an external research institution. Students will work under the supervision of a professor of our faculty. Their work will culminate in a master’s thesis, to be written by each student individually and independently. The thesis work may also be done in an industrial R &/or D department, provided a professor of the Faculty of Applied Chemistry supervises the project. Each student will</td></tr>
</table>

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	research a defined scientific topic, present his/her findings to a board of experts and prepare a scientific publication of the results. Work on the thesis will be accompanied by regular attendance of seminars on the topic of research.
Study and exam requirements	Master's Thesis: The processing time for the master's thesis is six months. The thesis will be evaluated by the mentoring professor as well as by a second reviewer. Seminar on topics related to master's thesis: After completing the master's thesis, students will hold an oral presentation on their work.
Media used	Oral presentation, written thesis, digital projector, PowerPoint slides
Literature	Depends on actual research project

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PPM14 – Internship semester (Add. Module only for stud. with 180 ECTS BSc's degree)

Course of studies	Polymer & Process Analytical Chemistry (MSc)
Module	**Internship semester**
Abbreviation	PPM14
Course(s)	• Internship semester
Semester	1
Person responsible for the module	Prof. Dr. Andras Kandelbauer
Instructor	All instructors of faculty
Language	English or German
Status within the curriculum	possibly Mandatory
Type of course / WH	Course | L | E | LW | S Internship semester | - | - | - | -
Workload in hours	Course | Class attendance | Study outside of class | Total | CP Internship semester | | 900 | 900 | 30 **Total** | | **900** | **900** | **30**
Credit points	30
Prerequisites for attending this course	If the first academic degree required for this Master's degree program is less than 210 ECTS credits, any missing ECTS credits, as determined by the Examination Board, can be made up through an internship semester. The internship semester must be completed at the latest before the beginning of the master's thesis.
Recommended knowledge / course work	Successful completion of semesters 1 and 2
Module goals / desired outcome	After successful completion of this module: • Students have a profound insight into the structure, organization and operations of an industrial company or a research institution. (K2) • Students are aware of the independent processing of specific tasks within projects. (K2) • Students are able to determine the status of development / research by literature search. (K4) • Students have acquired the skills for independent implementation of projects. (K4) • Students have gained the competence for a systematic and a structured approach. (K5) • Students have gained the competence to work scientifically. (K6) • Students have experienced the manners and practices in the work environment. (K2) • Students have improved their team and communication skills through participation in the working group. (K3) • Students interact successfully in intercultural surroundings. (K4)

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Content	The internship semester is performed in close co-operation between the internship site, the student and the internship Office of the school of Applied Chemistry. In 24 weeks, interns work on projects in their industrial enterprises or their institutions, which are connected to the thematic study content of the curriculum.
Study and exam requirements	The internship semester is supervised and regulated by the School of Applied Chemistry which awards 30 ECTS credits for the successful completion of the internship. Exam components are: Continuous assessment, regular reporting, preparation of a project report manuscript, certificate of the internship site. Further details are regulated by a guideline of the examination board.
Media used	“Richtlinie für das Nachholen fehlender Kompetenzen im Master-Studiengang Polymer & Process Analytical Chemistry” of the examination commission
Literature	Depends on actual project

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