Coversheet

Examination Regulations for the Master's Degree Program in Materials Science
in the Faculty of Natural Sciences at Paderborn University

Of 20

On the basis of Section 2 para. 4 and of Section 64 para. 1 of the Higher Education Act of the Region of Nordrhein-Westfalen (Gesetz über die Hochschulen des Landes Nordrhein-Westfalen (Hochschulgesetz – HG)) of September 16, 2014 (GV.NW. p. 547), Paderborn University has issued the following Examination Regulations:

Contents

I. General

§ 1 Objectives of the program and purpose of the examination

(1) The master's program in Materials Science teaches students advanced knowledge, skills and methods in materials sciences. They are then qualified to tackle and critically analyze problems independently at a high scientific level in this area.

(2) The "Master of Science" examination in the master's program in Materials Science represents the second professional qualification. The master's examination is intended to determine whether the candidate has acquired a deep knowledge of materials sciences through the program and his or her involvement in interdisciplinary projects. Furthermore, the candidate is expected to demonstrate that she or he has an overview of the interrelationships in the subject and has the capacity to develop and apply scientific methods and insights and, as a result, to make independent contributions in scientific teamwork.

(3) By preparing a master's thesis, the candidate provides evidence that she or he is in a position to resolve a specific problem scientifically and to summarize this in writing.

(4) The program is held in English. All written and oral examinations are held in English.

§ 2 Academic degree

If the master's examination is passed, the Faculty of Natural Sciences shall award the academic degree of Master of Science (M.Sc.).

§ 3 Commencement of the program

(1) The program commences in the winter semester.

(2) The master's degree program in Materials Science is built up semester by semester starting from the winter semester 2017/2018 (successive structure). In the winter semester 2017/2018, only courses and modules shall be offered that are recommended in the program plan for the 1st semester of study. This applies accordingly to subsequent semesters.

§ 4 Admission requirements

(1) Applicants may be enrolled in the master's degree program in Materials Science only if they have acquired the following:

1. A certificate of university entrance (general or specific to a relevant subject) or, in accordance with a legal ordinance, a certificate of entrance to a university of applied sciences or a certificate of previous educational qualification recognized as equivalent by legal regulation or by the relevant state authority, or satisfaction of the requirements for qualification through professional training or the requirements of the regulations for admission for applicants from abroad (Bildungsausländerhochschulzugangsverordnung).
2. A degree qualification that meets the following requirements:
   a) It must be an initial university degree with professional qualification with a normal study period of at least six semesters from Paderborn University or a state or state-recognized university or a state or state-recognized university of cooperative education. Degree

qualifications from a foreign state or state-recognized university allow admission provided that the competence acquired does not differ significantly from a degree from Paderborn University as per clause 1. For foreign educational qualifications, the equivalence agreements of the Conference of Education Ministers and the Conference of University Rectors or corresponding statutory regulations shall be observed. Insofar as agreements and conventions of the Federal Republic of Germany with other states about equivalence in the university sector (equivalence agreements) work to the advantage of students of foreign countries notwithstanding clause 2, the regulations of the equivalence agreement shall take precedence. In the event of doubt about the existence or absence of significant differences, the Central Agency for Foreign Education (Zentralstelle für ausländisches Bildungswesen) shall also be consulted. The Examinations Board shall determine compliance with the requirements of clause 2.

b) The degree qualification must be a degree qualification with the title Physics, Chemistry or Materials Science. Alternatively, the degree qualification must include the competences described below or there must be no significant differences from them:

aa) Principles of physics: Command of the principles of mechanics, thermodynamics, electro-dynamics, atomic physics, quantum mechanics, and solid-state physics, combined with the ability to create models and abstract mathematical formulations of physical phenomena.

bb) Practicals: Identifying and extracting significant scientific interrelationships using experiments conducted by the applicant herself or himself, recording and critically evaluating the results of experiments. The ability to use basic chemical, physical and materials science experimental apparatus and measurement methods reliably.

cc) Principles of chemistry: Command of the principles of inorganic, organic and physical chemistry, materials systems, energetics, bonding theory, the basic procedures of spectroscopy.

dd) Higher mathematics: Command of the basic mathematical concepts and methods that are required to understand and solve problems in the master's degree in Materials Science. This comprises advanced knowledge in the fields of linear algebra, analysis, Fourier series, differential equations, and vector analysis. The Examinations Board shall determine compliance with these requirements. If requirements are missing which can nevertheless be met by taking courses worth up to 30 ECTS credits, the Examinations Board may, in consultation with the candidate, determine which additional courses must be completed as a further requirement for enrollment.

c) The degree program must have been completed with an overall grade of at least 3.0 (or an equivalent final grade from abroad).

3. An adequate command of English, in accordance with the specifications of para. 2.

4. For a foreign applicant who is not on an equal footing with German applicants as a result or on the basis of state treaties, demonstration of her or his capacity to study by means of the results of a Graduate Record Examination (GRE) Revised General Test. A minimum of 157 points in the "Quantitative Reasoning" section and a minimum of 4.5 points in the "Analytical Writing" section of the GRE Revised General Test are usually required. The Examinations Board may accept a lower points score, depending on the qualification, if the final grade of the qualification in accordance with no. 2 is very good. Applicants with a German university entrance qualification are exempt from demonstrating their ability to study.

(2) Adequate command of the English language shall be demonstrated as follows:

a) A bachelor's degree from an English-speaking country or on an English-language accredited domestic program or

b) Test of English as a Foreign Language (TOEFL) “internet-based” Test (iBT) with a result of at least 80 points or

c) TOEFL “paper-based” test (PBT) with a result of at least 550 points or

d) International English Language Testing System (IELTS) test with a result of at least 6.0 or

e) Cambridge Test – First Certificate in English (FCE) or

f) tests of an equivalent level or

g) appropriate previous qualification from school.

(3) Enrollment shall be declined if

1. the admission requirements from para. 1 to 2 have not been met,
2. the candidate definitively failed to pass an examination required under the Examination Regulations in the relevant program at a university within the scope of the Basic Law or
3. the candidate definitively failed to pass any other examination required under the Examination Regulations in a program at a university within the scope of the Basic Law if both the failed program is close in content to the master’s program in Materials Science at Paderborn University and the examination that has been definitively failed has significant proximity in terms of content to an examination in a compulsory module on the master’s degree program in Materials Science at Paderborn University.

§ 5 Normal study period and scope of study

(1) The normal study period for the master’s degree program in Materials Science is four semesters, including the master’s thesis. This corresponds to a total workload of 3,600 hours.

(2) The master’s program comprises modules with a total of 120 credit points. One credit point (CP) corresponds to one ECTS point in accordance with the European Credit Transfer System. One CP corresponds to an average workload of 30 hours. A semester usually comprises 30 CP and thus a workload of 900 hours.

(3) Of the 120 CP in the master’s degree,

51 CP are for compulsory modules to be completed by all students,

34 CP are for elective modules,

5 CP are for the General Studies module,

24 CP are for the master’s thesis and 6 CP for the oral defense of the master’s thesis.

§ 6 Modules

(1) Study is modularized in the master’s program. Modules normally comprise multiple courses that are linked thematically. The modules are worth 5 to 8 CP and are designed in such a way that they can usually be completed within one or two semesters.

(2) A module is completed by passing a module examination. The credit points indicated in the curriculum and the module description are awarded for successful completion of the module.

(3) The modules are compulsory or elective modules. They consist of the compulsory and elective courses listed in Appendix 2. The elective modules are organized in four thematic areas:

I) Materials analysis

II) Materials chemistry and processing

III) Functional materials

IV) Computer-aided materials sciences.

At least one module must be taken from three of these four areas. In total, two modules worth 5 CP and four modules worth 6 CP must be taken from the elective area. Beyond that, the student is responsible for choosing her or his specialization.

§ 7 Recognition of academic work

(1) Academic work on other programs or on programs at other state or state-recognized universities, at state or state-recognized universities of cooperative education or on programs at foreign state or state-recognized universities shall be recognized if there is no significant difference in the competences acquired from the academic work that is being replaced. This process does not involve a schematic comparison, but an overall consideration of the purpose of recognition for the continuation of study and completion of examinations. Clauses 1 and 2 apply accordingly to the recognition of academic work acquired on state-recognized distance programs or in distance study units developed by the region of Nordrhein-Westfalen in conjunction with the other regions and the Federal Republic as a whole.

(2) The equivalence agreements approved by the Conference of Education Ministers and the Conference of University Rectors and agreements in the context of university partnerships shall be observed in recognizing academic work from foreign universities. Insofar as agreements and conventions of the Federal Republic of Germany with other states about equivalence in the university sector (equivalence agreements) work to the advantage of students of foreign countries notwithstanding paragraph 1, the regulations of the equivalence agreement shall take precedence. In the event of doubt about the existence or absence of significant differences, the Central Agency for Foreign Education (Zentralstelle für ausländisches Bildungswesen) may also be consulted.

(3) On request, the Examinations Board must assign the student to a semester on the basis of recognition in accordance with para. 1.

(4) Applicants who are entitled to start a program on the basis of a classification examination in accordance with Section 49 para. 12 HG shall have the knowledge and skills they demonstrate in the classification examination recognized as completed academic work. The assessments on the certificate for the classification examination are binding for the Examinations Board.

(5) On application, other knowledge and qualifications based on submitted documentation may be recognized by the Examinations Board if that knowledge and those qualifications are equivalent in content and level to the academic work that they are intended to replace.

(6) The Examinations Board is responsible for recognition in accordance with paragraphs 1 and 5. Before determining the existence or absence of significant differences or equivalence, relevant subject representatives shall be consulted. If recognition is refused, the reasons for the decision must be given.

(7) The applicant shall provide the information required (in particular, the knowledge and skills acquired through the academic work and the examination results) for recognition in the form specified by the Examinations Board. The Examinations Board shall decide on applications under paragraph 1 at the latest within ten weeks of full submission of all information required for the decision.

(8) Recognition shall be indicated on the certificate. If academic work is recognized, the grades shall be transferred following conversion as necessary, insofar as the assessment systems are comparable, and included in the respective grade calculation. If no grade is available or if the assessment systems are not comparable, the comment “passed” shall be entered.

(9) A piece of academic work can only be recognized once. This also applies to recognition of other knowledge and qualifications.

II. Examination organization

§ 8 Examinations Board

(1) The Faculty Board of the Faculty of Natural Sciences shall constitute an Examinations Board for the master's degree program in Materials Science. It is responsible, in particular, for

a) the organization of examinations and monitoring of the way in which they are conducted,

b) compliance with the Examination Regulations and adherence to the procedural regulations agreed for conducting the examinations,

c) decisions on inconsistencies in decisions made in examination procedures,

d) drafting of an annual report to the Faculty Board on developments in examinations and study periods,

e) any other tasks expressly assigned to the Examinations Board by these Regulations.

In the case of subject-specific decisions (e.g. recognition of academic work), the Examinations Board shall call on the expertise of the relevant subject representatives, for example by obtaining a written report and/or advice on the corresponding agenda item in the meeting of the Examinations Board.

In addition, the Examinations Board shall make suggestions for reform of the Examination Regulations and shall publish the distribution of grades. The Chair of the Examinations Board is assigned specific tasks by these Regulations. The Examinations Board may assign completion of matters that have no fundamental importance to the Chair; this does not apply to decisions about inconsistencies or to the annual report. The Chair shall report to the Examinations Board on decisions made by her or him alone. The Examinations Board and the Chair of the Examinations Board shall be supported by the Examinations Office.

(2) The Examinations Board consists of the Chair, the Deputy Chair, and five further members. At the suggestion of the respective group, the Chair, the Deputy Chair and two further members from the group of lecturing staff, a member from the group of academic assistants, and two members from the group of students are elected by their respective representatives on the Faculty Board. With the exception of the Chair and the Deputy Chair, deputies for the members of the Examinations Board shall be elected accordingly. The period in office of the members from the group of lecturing staff and from the group of academic assistants is three years, the period in office of the students is one year. Re-election is permitted. The regulations regarding gender equality pursuant to Section 11c HG must be observed in the composition of the Board.

(3) The Examinations Board is an authority as defined by administrative procedural and administrative process law.

(4) The Examinations Board has a quorum if, in addition to the Chair or the Deputy Chair and two further members from the group of lecturing staff, at least one other member with voting rights is present. The Examinations Board shall make decisions by simple majority. In the event of an equal number of votes being cast, the Chair shall have the casting vote. The student members of the Examinations Board act in an advisory capacity only in pedagogical-academic decisions, in particular in the assessment and recognition of academic work.

(5) The Examinations Board is convened by the Chair. The Examinations Board must be convened if at least three of its members so demand.

(6) The meetings of the Examinations Board are not public. The members of the Examinations Board and their representatives are *ex officio* obliged to maintain confidentiality. If they are not civil servants, they shall be obliged to maintain confidentiality by the Chair of the Examinations Board.

(7) The members of the Examinations Board have the right to attend the examinations when they are being taken.

(8) The Chair of the Examinations Board may invite the Chairs of the respective Examinations Boards for the degree programs in Mechanical Engineering and/or Electrical Engineering to attend its meetings to advise on agenda items that relate to technical issues from the fields of Mechanical Engineering or Electrical Engineering.

§ 9 Examiners and observers

(1) The Chair of the Examinations Board shall appoint the examiners and observers. The examiners are usually all independent teachers of the courses in which examinations may be taken in accordance with the specifications of the curriculum and the module descriptions. Those who have at least passed the relevant master's examination or a comparable examination may be appointed as observers.

(2) Examiners are independent in their examination work.

(3) The candidate may propose examiners for the master's thesis and – if several examiners are available to choose from – for the oral examinations. The proposals shall be accommodated as far as possible. There is no legal entitlement.

(4) The Chair of the Examinations Board shall ensure that the candidate is notified of the names of the examiners in good time, usually four, but at least two weeks before the date of the corresponding examination. Publication by a notice on the Campus Management System is sufficient.

(5) Examiners and observers are *ex officio* under an obligation to maintain confidentiality. If they are not civil servants, they shall be obliged to maintain confidentiality.

III. Examinations

§ 10 Master's examination

The master's examination consists of assessments that are completed on the master's degree program in Materials Science, the master's thesis (24 CP), and an oral defense of the master's thesis (6 CP).

§ 11 Admission to examinations

(1) Only those who are enrolled for the master's degree program in Materials Science at Paderborn University or are registered as visiting students in accordance with Section 52 HG may be admitted to examinations for the master's degree program in Materials Science. These requirements must also be observed during the examinations.

(2) Those who have successfully completed module examinations worth 90 CP shall be admitted to the master's thesis.

(3) Registration for admission to the master's thesis shall be submitted in writing to the Chair of the Examinations Board via the Central Examinations Office. Evidence of compliance with the admission requirements specified in paragraphs 1 and 2 shall be appended to the registration.

(4) Admission shall be refused if the requirements specified in paragraphs 1 to 3 are not met.

(5) Further requirements for participation in examinations may be stipulated in the module descriptions.

§ 12 Completion of a module and registration for examinations

(1) Every module on the master's degree program ends with a module examination. Credit points may be acquired only insofar as the module has been completed in full. As a matter of principle, this module examination shall take place in temporal proximity to the module. A module examination usually takes the form of an examination at the end of the module (final module examination). However, the module examination can also take place in the course of the module (in particular, in temporal proximity to a course) or consist of several partial examinations (partial module examinations). If the module examination consists of several partial module examinations, each partial module examination must be passed.

(2) Separate registration is required for each examination via the Campus Management System of Paderborn University. Registration is possible only if the admission requirements have been met. Registration shall be completed within the periods published on the Campus Management System of Paderborn University.

§ 13 Assessments in the modules

(1) Assessments shall be taken in each module of the master's degree program in Materials Science. The grades from the module examinations go towards the final grade for the master's examination. They are weighted according to the credit points achieved.

(2) A module is completed when all assessments have been completed, i.e. the final module examination or partial module examinations have been passed with a minimum grade of "adequate". The module grade corresponds to the grade achieved in the module examination.

(3) If the module descriptions include overall guidelines as to the form and/or duration/extent of assessments, the Examinations Board shall define in consultation with the examiner how, specifically, the assessment is to be completed. In all courses, confirmation of how the assessment is to be completed shall be given at the latest in the third week from the start of teaching by the teacher concerned. Assessments are related to the content and skills acquired in the associated courses.

(4) These Examination Regulations apply to registration, cancellation of registration, withdrawal, unfair practice, breach of regulations, and grading of assessments in General Studies courses.

§ 14 Forms of assessment in the modules

(1) Assessments may take the form of written examinations, oral examinations, written homework, or other forms. The precise allocation of individual assessments is indicated in the module descriptions in the Appendix. With the exception of oral examinations, students shall usually be notified of their grade on the Campus Management System of Paderborn University at the latest six weeks after the assessment has been completed.

(2) A distinction is made between the following types of assessment:

a) Written examinations

In written examinations, the candidate is expected to demonstrate that she or he is able to identify problems in the subject area in a specified time using resources permitted by the examiner and to solve them using standard methods.

Written examinations are usually graded by one examiner. A final attempt at an examination shall be graded by two examiners.

The duration of a written examination is determined by the total number of credit points for the module. It is usually 60-180 minutes. The examiner shall determine which resources may be used

in a written examination. A list of approved resources shall be announced with the date of the examination.

b) Oral examinations

In the oral examinations, the candidate is expected to demonstrate that she or he can recognize the interrelationships within the examination area and can classify specific questions in this context. Oral examinations are also intended to establish whether the candidate has a broad basic knowledge.

Oral examinations, including examinations pursuant to Section 21 paragraph 5 (substitute oral examinations), shall be held in front of at least two examiners (examination before a panel) or in front of one examiner in the presence of a knowledgeable observer, as group or individual examinations. Before determining the grade, the examiner shall listen to the views of the other examiners on the panel or the observer without the candidate being present. A final attempt at an examination shall be graded by two examiners.

The duration of an oral examination for each candidate (including an examination pursuant to Section 21 paragraph 5) is determined by the total number of credit points for the module on which it is based. It is 30-45 minutes.

The key points and results of the examination shall be recorded in a report. The candidate shall be notified of the result by the examiner following the oral examination.

Students who want to take the same examination at a later examination date shall be admitted to listen to the examination if space permits and provided that there is no objection from a candidate. Admission does not include advice or notification of the result of the examination to the candidate.

c) Written project report with final presentation

A written project report is a presentation, by the student, of an assigned topic of a length specified in the module description. The length is specified in the module description. The examiners shall follow the same regulations as for the grading of written and oral examinations.

d) Assessment of practicals

The assessment comprises all of the experiments to be carried out in a practical. Each experiment normally consists of (i) a preliminary presentation of 15 to 20 minutes (oral evidence that the candidate has prepared for the content of the experiment with regard to theoretical and safety aspects), (ii) conducting the experiment to an appropriate level of quality, (iii) a report, 5 to 10 pages in length (written account of the theoretical background, description of the method of the experiment and documentation and evaluation of the results).

e) Presentation

A presentation is a structured oral examination of a limited topic, of a length specified in the module descriptions. The content may be a presentation of the student's own research work or a critical report on scientific publications.

(3) Oral or written assessments are held in General Studies. These usually comprise written examinations (maximum of four hours), an essay (maximum of 25 pages), or an oral examination (maximum 45 minutes).

§ 15 Grading of assessments in the modules

(1) The grades for the individual assessments are determined by the respective examiners. The following grades shall be used for assessment:

1= very good:	an outstanding performance;
2 = good:	a performance significantly above the average requirements;

3 = satisfactory:	a performance that meets the average requirements;
4 = adequate	a performance which, despite its defects, still satisfies the requirements;
5 = unsatisfactory:	a performance which no longer satisfies the requirements because of serious defects.

(2) For more differentiated grading, intermediate grades can be created by raising or lowering the individual grade by 0.3. The intermediate grades 0.7, 4.3, 4.7, and 5.3 are not permitted.

(3) If an examination is graded by several examiners and the results vary, the grade shall be determined by the arithmetic mean of the grades of all examiners. Otherwise, paragraph 4 applies accordingly.

(4) If a module grade is made up of several grades together, the arithmetic mean shall be taken, weighted according to the workload of the courses and correct to one decimal place. Further decimal places are not included. Other weightings may be used according to the module descriptions. The average grades are as follows:

for an average up to and including 1.5	= very good,
for an average over 1.5 up to and including 2.5	= good,
for an average over 2.5 up to and including 3.5	= satisfactory,
for an average over 3.5 up to and including 4.0	= adequate,
for an average over 4.0 up to and including 5.0	= unsatisfactory.

(5) Academic performances are graded “pass” or “fail.”

§ 16 Master’s thesis

(1) The master’s thesis is an assessment worth 24 credit points with which the master’s degree program is completed. It is intended to demonstrate that the candidate is in a position to solve a problem from a subject area of his or her degree program independently using scientific methods within a specific period and to present the results appropriately.

(2) The master’s thesis shall be completed over a period of five months once all module examinations have been passed. It shall normally commence at the latest four weeks after all of the module examinations have been passed.

(3) The commencement of the master’s thesis when the topic is assigned shall be recorded by the Central Examinations Office. The topic and question for the thesis shall be circumscribed in such a way that the thesis can be completed in the specified time. The topic may be returned only once and within two months. The completion time begins again when the new topic is assigned. In individual cases, the Examinations Board may extend the completion period for the master’s thesis on justified application by up to six weeks, if the supervisor agrees.

(4) The master’s thesis may be assigned and supervised by university lecturers, junior professors, private and university tutors, academic assistants with Habilitation, assistants with Habilitation and heads of junior research groups in the Faculty of Natural Sciences, Mechanical and Electrical Engineering who are involved in research and teaching. If the master’s thesis is to be completed at an establishment outside the University, the approval of the Chair of the Examinations Board and a supervisor belonging to one of the groups in the first clause is required. The candidate has the right to propose the supervisor and the topic. However, this does not justify any legal claim.

(5) If the candidate falls ill during the completion time, she or he may apply for an extension to the submission deadline for the master’s thesis of a maximum of four weeks. Immediate submission of a medical certificate is essential in this case. A medical certificate confirming incapacity to take the examination is sufficient. If there is sufficient factual evidence to suggest that incapacity to complete

the examination is likely or other evidence that appears to be relevant, a medical certificate from a medical officer of Paderborn University may be demanded at the cost of the University. If the Examinations Board accepts the application, the candidate shall be notified in writing. The extension shall correspond to the period of illness; it does not entail an extension of the normal study period. If the period of the illness exceeds four weeks, the candidate may, at her or his discretion, complete the thesis within the deadline extended by four weeks or apply for a new topic. If the Examinations Board rejects the application, the candidate shall likewise be notified in writing.

(6) The master's thesis is written in English. An application may be made to write it in another language. The decision shall be made by the Examinations Board when the topic is assigned, as appropriate. The thesis must satisfy the subject guidelines in terms of form and content. The thesis must include a title page, a summary of contents, a list of references, and a bibliography. The points in the thesis that are taken from other works as far as wording or meaning are concerned must always be made clear with an indication of the source from which they are taken. The candidate shall append a written assurance to the thesis that she or he has written the thesis herself or himself, has not used sources or aids other than those indicated, and has marked quotations as such. This assurance shall also be given for tables, sketches, drawings, images, etc. Attention is drawn to Section 63 para. 5 HG.

(7) The master's thesis, including extracts thereof, must not have been prepared for any other completed examination.

§ 17 Submission and grading of the master's thesis

(1) Three copies of the master's thesis (word-processed, bound, and paginated) shall be submitted on time to the Central Examinations Office. An electronic version of the master's thesis shall also be submitted. The time of submission shall be recorded. If the thesis is submitted by post, the time of submission to the post office (postmark) is definitive. If the master's thesis is not submitted on time, it shall be graded "unsatisfactory" (5.0).

(2) The master's thesis shall be assessed and graded by two examiners. At least one of the examiners must be a member of the Faculty of Natural Sciences, Mechanical and Electrical Engineering and at least one must be a member of the University lecturing staff or have Habilitation. The examiners shall include, in particular, the person who set the topic. The second examiner shall be determined by the Chair of the Examinations Board. The candidate has the right to make a proposal. However, this does not justify any legal claim. The individual grading shall be carried out in accordance with Section 15 and shall be justified in writing. The grade for the thesis shall be determined by the arithmetic mean of the individual grades in accordance with Section 15, provided that the difference is not greater than 2.0 and the grades for the individual assessments are a minimum of "adequate". If the difference is greater than 2.0 or one of the grades is "unsatisfactory" while the other is "adequate" or better, a third examiner shall be appointed by the Examinations Board to assess the master's thesis. In this case, the grade for the thesis shall be determined by the arithmetic mean of the three grades. However, the thesis may only be assessed as "adequate" or better if at least two of the grades are "adequate" or better.

(3) The assessment procedure for the master's thesis shall not take more than four weeks. The student shall be notified of the grade at the latest five weeks after submission of the master's thesis.

§ 18 Oral defense of the master's thesis

(1) At the latest four weeks after submission, an oral defense of the master's thesis shall be held in English. It shall last a minimum of 30 minutes and a maximum of 45 minutes. 6 CP are awarded for the defense.

(2) During the oral defense of the master's thesis, the candidate shall briefly present and explain its main themes and findings.

(3) The oral defense of the master's thesis shall take place in front of two examiners, who are usually identical with the assessors of the master's thesis pursuant to Section 17 para. 2. If the grades deviate from one another, the grade shall be determined by the arithmetic mean of the two individual grades. The master's thesis and oral defense contribute to the overall grade for the master's thesis module with a weighting factor of 1/3.

(4) The key points and results of the oral defense shall be recorded in a report. The candidate shall be notified of the result by the examiners following the oral defense.

(5) If the assessment of the oral defense is unsatisfactory, it may be repeated once. If the oral defense is failed definitively, the master's thesis is also deemed to have been failed. In this case, Section 21 para. 7 applies.

§ 19 Additional courses

(1) In addition to the courses required for the degree program, students may complete further courses beyond those stipulated for the master's examination (additional courses). Regulations on modules with a cap on participants pursuant to Section 59 HG remain unaffected. The additional courses shall not be taken into account in determining the grade for the module or master's examination. The module grades achieved in additional courses shall be listed on the Transcript of Records. At the request of the student, they may not be included on the Transcript of Records.

(2) The additional courses shall be applied for as such on application for admission. It is not possible to swap an additional course for a compulsory or elective course in retrospect, or vice versa.

§ 20 Assessment of the master's examination and determination of overall grade

(1) The master's examination has been passed when all module examinations, the master's thesis, and the oral defense have received a minimum grade of "adequate" (4.0). The requirements for successful completion of the program are specified in Section 23.

(2) The overall grade is determined by weighting the module grades and the grade for the master's thesis and its oral defense according to credit points and calculating the arithmetic mean. In calculating the result, only the first decimal place shall be taken into consideration; all other decimal places shall be deleted without rounding.

The grades are:

for an average	up to and including 1.5 = very good
for an average	over 1.5 up to and including 2.5 = good
for an average	over 2.5 up to and including 3.5 = satisfactory
for an average	over 3.5 up to and including 4.0 = adequate
for an average	over 4.0 up to 5.0 = unsatisfactory

(3) The overall grade for the master's examination is "passed with distinction" if the master's thesis and the oral defense are both assessed with a grade of 1.0 and the average grade for all other modules (without the master's thesis and oral defense) is 1.0 to 1.3.

§ 21 Retaking assessments

(1) A final module examination or partial module examination that has been passed can neither be retaken nor improved.

(2) A final module examination or partial module examination that has been failed can be retaken three times. If an examination is being retaken, the same course may be repeated or, if the course choice allows, a different course permitted for the relevant final module examination or partial module examination may be selected.

(3) If no further retakes are possible, the examination has been definitively failed.

(4) Examinations are usually held twice in the academic year. Retakes are usually offered at the latest eight weeks from the date of the first examination.

(5) If the master's thesis and the oral defense are "unsatisfactory", they may be repeated once and immediately. In the case of a retake of the master's thesis, a return of the topic within the period specified in Section 16 para. 3 is only permitted, however, if the option to return the topic was not exercised in the first attempt.

§ 22 Withdrawal, failure to appear, unfair practice, breach of regulations, protection provisions, and students with family obligations

(1) Withdrawal of registration for examinations is possible on the Campus Management System of Paderborn University without specifying reasons up to a week before the respective examination date. For modules M6 and M8, withdrawal is possible at the latest one week before the first day in the laboratory.

(2) An assessment is deemed to be "unsatisfactory" (5.0) if the candidate fails to appear at an examination without good reason or leaves after the start of the examination without good reason or withdraws from the examination after the registration periods specified under para. 1 have elapsed without giving good reason. The same applies if a written assessment is not completed within the specified time.

(3) The reasons asserted for the withdrawal must be made known to the Examinations Board immediately in writing to its satisfaction, and at the latest five working days from the respective examination date. In the event of illness of the candidate, a medical certificate dated on the day of the examination at the latest confirming incapacity to take the examination is sufficient. If there is sufficient factual evidence to suggest that incapacity to complete the examination is likely or other evidence that appears to be relevant, a medical certificate from a medical officer of Paderborn University may be demanded at the cost of the University. The medically certified illness of a child, as defined under Section 25 para. 5 of the German Federal Education and Training Assistance Act, constitutes incapacity of the candidate to take the examination if alternative arrangements for childcare cannot be made, in particular if parental care is provided mainly by the candidate alone. If the Examinations Board accepts the reasons, the candidate shall be notified in writing and a new examination date shall be set. The examination results already available shall count in this case. If the Examinations Board does not accept the reasons, the candidate shall be notified in writing.

(4) If a candidate engages in unfair practice or attempts to engage in unfair practice, the examination concerned is deemed to have been given the grade "unsatisfactory" (5.0). If a candidate uses an unauthorized aid, the assessment concerned may be given the grade "unsatisfactory". The incidents shall be recorded by the supervisors concerned. The determination pursuant to clause 1 or the decision pursuant to clause 2 shall be made by the respective examiner.

(5) A candidate who disrupts the orderly course of the examination may be excluded from continuing to sit the examination, usually following a warning, by the respective examiners or supervisors; in this case, the assessment is deemed to have been given the grade "unsatisfactory" (5.0) or "fail". The reasons for the exclusion shall be recorded.

(6) In serious cases of unfair practice or disruption, the Examinations Board may exclude the candidate from taking further assessments. Unfair practice may also incur a financial penalty of up to €50,000

in accordance with Section 63 para. 5 HG and lead to exmatriculation (removal from the register of students).

(7) The candidate may demand, within 14 days, that decisions under para. 4 clauses 1 and 2 and para. 5 be reviewed by the Examinations Board. The candidate shall be notified of negative decisions immediately in writing by the Examinations Board and provided with the reasons and with information about legal remedies. Before the decision is made, the candidate shall be given the right to be heard.

(8) The Examinations Board shall also decide on compensation for disadvantages for students with a disability or chronic illness. If, as a result of her or his disability or chronic illness, the student is not in a position to complete assessments in whole or in part using the intended methods, compensation for the disadvantage shall be granted. Compensation for disadvantage to be considered includes taking organizational measures or providing organizational aids, extending deadlines, or offering a different, equivalent form of assessment. Evidence of disability or chronic illness must be provided. A medical report or psychological assessment may be required for this purpose. The application shall specify and justify the modifications requested. At the request of the student or of the Examinations Board in agreement with the student, the Officer for Students with Disabilities or Chronic Illnesses may provide recommendations for the form of compensation for disadvantage.

(9) Account shall be given to the particular situation of students with family obligations when studying and completing assessments. This can be done in the following ways, among others:

a) At the request of a candidate, the protective provisions pursuant to Sections 3, 4, 6 and 8 of the German Maternity Protection Act shall be observed as appropriate. The necessary evidence shall be attached to the application. The Examinations Board may decide on alternative forms of assessment, taking the individual case into account. The maternity protection periods shall interrupt all periods specified by these Examination Regulations; the duration of the maternity protection shall not be included in the period concerned.

b) Similarly, the periods of parental leave in accordance with the applicable German Federal Parental Benefit and Parental Leave Act shall be taken into account on request. The candidate shall notify the Examinations Board in writing, attaching the necessary evidence, of the period or periods for which she or he wishes to take parental leave at the latest four weeks before the time from which she or he wishes to take parental leave. The Examinations Board shall check that the statutory requirements which would trigger a right to parental leave for an employee under the Federal Parental Benefit and Parental Leave Act have been met and shall set the deadlines and periods in accordance with the individual case. The submission period for the master's thesis may be extended to a maximum of twice the intended completion period. Otherwise, the thesis is deemed not to have been assigned and the candidate shall be given a new topic upon expiry of the parental leave.

c) On request, the Examinations Board shall take account of absences resulting from the care and upbringing of children as defined by Section 25 para. 5 of the Federal Education and Training Support Act and absences for the care of a spouse, registered civil partner, or partner in a cohabitation relationship, or of an immediate relative or immediate in-law, and shall set periods and deadlines in accordance with the individual case. Clauses 4 and 5 of letter b) also apply accordingly.

§ 23 Successful completion of the program, definitive failure

(1) The program has been successfully completed when the master's examination has been passed and all modules have been completed successfully. The master's examination has been passed

when all module examinations, the master's thesis, and the oral defense have received a minimum grade of "adequate" (4.0).

(2) The master's examination has been failed definitively if a module has been failed definitively or the master's thesis has been failed definitively.

(3) The decision of a definitive failure of the master's examination shall be communicated to the candidate in written form by the Chair of the Examinations Board. The decision shall be communicated with information about possible legal remedies.

(4) If a candidate has definitively failed the master's examination, on request she or he shall be issued with a transcript which includes the assessments completed with any credit points (ECTS credits) awarded and grades achieved, and which indicates that the master's examination has been failed definitively.

(5) On request, students who withdraw from the University for other reasons without graduating shall be issued with a transcript following exmatriculation, which includes the assessments completed and any credit points (ECTS credits) awarded.

§ 24 Certificate, Transcript of Records, Diploma Supplement

(1) If the candidate has successfully completed the program, she or he shall receive a certificate confirming the result. This certificate shall include the name of the program, the normal study period, and the overall grade. The certificate shall indicate the date on which the last assessment was completed. It shall also show the date on which it was issued. The certificate shall be signed by the Chair of the Examinations Board.

(2) In addition, the candidate shall receive a Transcript of Records in which all of the assessments completed and the study period are listed. The Transcript of Records includes details of the credit points (ECTS credits) and the grades achieved for the completed modules and for the master's thesis. It also includes the topic of the master's thesis and the overall grade achieved for the master's examination.

(3) With the final certificate, the graduate shall also be issued with a Diploma Supplement.

(4) The Diploma Supplement is an addition to the certificate in English and German with standard information about German university degree qualifications; it explains the German education system and the place of the present degree qualification in it. The Diploma Supplement provides information about the completed degree program and the academic and professional qualifications achieved with it. It includes the central content of the program on which it is based, the program of study, the skills achieved on graduation, and the awarding university.

§ 25 Master's Certificate

(1) Along with the certificate for completion of the degree, the candidate shall be provided with a Master's Certificate with the date of the certificate. This certifies the awarding of the master's degree in accordance with Section 2.

(2) The Master's Certificate shall be signed by the Chair of the Examinations Board and the Dean of the Faculty of Natural Sciences and provided with the seal of Paderborn University.

(3) An English translation shall be attached to the Master's Certificate.

§ 26 Access to the examination files

(1) Following release of the grades, the candidate may be given the opportunity to have access to her or his written assessments and the evaluation of the examiners relating to them. The Chair of the

Examinations Board shall determine the location and time at which access is provided; she or he may assign these tasks to the examiners. The location and time at which access is provided shall be made known during the examination, at the latest on release of the grade.

(2) If paragraph 1 does not apply, on application within a month of release of the results of the respective examinations the candidate shall be given the opportunity to have access to her or his written assessments and the evaluations of the examiners relating to them and to the examination records. Within one year of issue of the certificate, the candidate shall be given access on request to the master's thesis, the related evaluations of the examiners, and the examination records within an appropriate period. The Chair of the Examinations Board shall determine the location and time at which access is provided; she or he may assign these tasks to the examiners.

IV. Final provisions

§ 27 Invalidity of the master's examination

(1) If a candidate has engaged in unfair practice in an examination and if this fact only becomes apparent after the certificate has been issued, the Examinations Board may subsequently adjust the grades accordingly for those examinations in which the candidate engaged in unfair practice and declare the examination failed in whole or in part.

(2) If the requirements for admission to an examination were not met, without the candidate intending to deceive, and if this fact becomes apparent only after the certificate has been issued, this defect shall be remedied by passing the exam. If the candidate has intentionally brought about admission by deceit, the Examinations Board shall decide on the legal consequences, taking account of the Administrative Procedures Act for the region of Nordrhein-Westfalen.

(3) The candidate shall be given the opportunity to speak before any decision is made.

(4) The incorrect examination certificate shall be retracted and, if appropriate, a new one shall be issued. A decision in accordance with paragraph 1 and paragraph 2 clause 2 is excluded after a period of five years from the date of issue of the examination certificate.

(5) If the master's examination as a whole has been declared to have been failed, the master's degree shall be withdrawn and the Master's Certificate retracted. Withdrawal of the master's degree is permitted only within five years of the date on which the degree was awarded.

§ 28 Withdrawal of the master's degree

The master's degree shall be withdrawn if it subsequently transpires that it has been obtained by unfair practice or if significant requirements for the award have mistakenly been considered to have been met. The Faculty Board of the Faculty of Natural Sciences shall decide on the withdrawal by a two-thirds majority of its members. The Master's Certificate shall be withdrawn. Withdrawal of the master's degree is permitted only within five years of the date on which the degree was awarded.

§ 29 Interim regulations, effectiveness and publication

(1) These Examination Regulations are valid for enrollment to winter term 2017/2018. The first term of office begins at April 1st 2017. The first term of office extend divergent from paragraph 8 clause 2 for members from group of professors and for members from academic staff up to September 30th 2019 and for the collegiate member up to September 30th 2018.

(2) These Examination Regulations shall come into force on the day after their publication

(3) These Examination Regulations shall be published in the Official Notices of Paderborn University (AM.Uni.Pb.).

Drafted on the basis of the resolution of the Faculty Board of the Faculty of Natural Sciences of xx.xx. 20 and checked for accuracy by the Executive Board of Paderborn University on xx.xx.20.

Paderborn, xx.xx.20xx

The President
of Paderborn University
Dr. Wilhelm Schäfer

Mandatory courses

Sem.	Course	Module	L	E/S	P	CP/WL
1	Fundamental Concepts of Materials Science	1	3	1		6/180
	Atomistic Materials Modeling	2	2	2		6/180
	Physics and Technology of Nanomaterials	3	2	1		5/150
	Characterization Techniques of Solids	4	2	1		5/150
	Macromolecular Chemistry / Structure-Property-Relations	5a	2			3/90
			11	**5**		**25**
2	Natural and Synthetic Functional Materials	5b	2			3/90
	Lab Course: Materials Physics and Analysis	6			3	5/150
	Fundamentals and Applications of Surface and Interface Spectroscopy	7	2	1		5/150
			4	**1**	**3**	**13**
3	Lab Course: Materials Chemistry and Analysis	8			3	5/90
	Current Topics in Materials Science	9a		2		3/90
	Project Based Course	9b			5	5/150
	General Studies	10	2	2		5/150
			2	**4**	**8**	**18**
4	Master Thesis	11a	20			24/720
	Concluding Colloquium	11b		2		6/180
			20	**2**		**30**
		S:	**37**	**12**	**11**	**86**

Elective courses

Sem.	Course	Module	L	E/S	P	CP/WL
1	Structure and Dynamics at Materials Interfaces and Nanostructures	12	2	1		5/150
	Polymer Analysis	13	2	1		5/150
	Quantum Chemistry	14	2	1		5/150
	Biopolymers and Biointerfaces	15a	2			3/90
	Bioinspired Materials	15b	2	1		3/90
			10	**4**		**21**
2	Computational Spectroscopy	16	2	2		6/180
	Semiconductor Epitaxy	17	2	2		6/180
	Processing of Semiconductors	18	2	2		6/180
	Inorganic Materials Chemistry	19	2	1		6/180
	Simulation of Materials	20	2	1		6/180
	NMR in Materials Science	21a	2			3/90
	Synchrotron Techniques for Materials Science	21b	2			3/90
	Special Polymer Synthesis	22a	2			3/90
			16	**8**		**39**
3	Liquid Crystals	22b	2			3/90
	Micro Electromechanical Systems	23	2	2		6/180
	Molecular thermodynamics	24	2	1		5/150
	Microscopy and Spectroscopy with Electrons	25	2	2		6/180
	Particle Synthesis	26	2	1		5/150
	Ion Beam Analysis	27	1	1	2	6/180
			11	**7**	**2**	**31**
		S:	**37**	**19**	**2**	**91**

L: Lecture
E: Exercise
S: Seminar
P: Practical course
CP: Credit points
WL: Workload

Topical overview of elective course-areas

I Materials Analysis
Interface Electrochemistry (M12)
Polymer Analysis (M13)
Advanced Materials Analysis (M21)
Advanced Electron Microscopy (M25)
Ion Beam Analysis of Materials (M27)

II Materials Processing
Semiconductor Epitaxy (M17)
Semiconductor Processing (M18)
Solid-State Materials Chemistry (M19)
Particle Synthesis (M26)

III Adv. Functional Materials
Biomaterials (M15)
Soft Matter (M22)
Micro Electromechanical Systems (M23)

IV Computational Materials Science
Quantum Chemistry (M14)
Computational Spectroscopy (M16)
Finite Elemente Modeling (M20)
Molecular Thermodynamics (M24)

Exemplary study plan

Mandatory courses

Sem.	Course	Module	L	E/S	P	CP/WL
1	Fundamental Concepts of Materials Science	1	3	1		6/180
	Atomistic Materials Modeling	2	2	2		6/180
	Physics and Technology of Nanomaterials	3	2	2		5/150
	Characterization Techniques of Solids	4	2	1		5/150
	Macromolecular Chemistry / Structure-Property-Relations	5a	2			3/90
		17	**11**	**6**		**25**
2	Natural and Synthetic Functional Materials	5b	2			3/90
	Lab Course: Materials Physics and Analysis	6			3	5/150
	Fundamentals and Applications of Surface and Interface Spectroscopy	7	2	1		5/150
		8	**4**	**1**	**3**	**13**
3	Lab Course: Materials Chemistry and Analysis	8			3	5/90
	Current Topics in Materials Science	9a		2		3/90
	Project Based Course	9b			5	5/150
	General Studies	10	2	2		5/150
		14	**2**	**4**	**8**	**18**
4	Master Thesis	11a	20			24/720
	Concluding Colloquium	11b		2		6/180
		22	**20**	**2**		**30**
		61	**S:**	**37**	**13**	**11**	**86**

Elective courses

Sem.	Course	Module	L	E	P	CP/WL
1	Structure and Dynamics at Materials Interfaces and Nanostructures	12	2	1		5/150
	Polymer Analysis	13	2	1		5/150
		4	**2**	**2**		**10**
2	Inorganic Materials Chemistry	19	2	1		6/180
	NMR in Materials Science	21a	2			3/90
	Synchrotron Techniques for Materials Science	21b	2			3/90
		7	**6**	**1**		**12**
3	Microscopy and Spectroscopy with Electrons	25	2	2		6/180
	Ion Beam Analysis	27	1	1	2	6/180
		6	**3**	**3**	**2**	**12**
		17	**11**	**6**	**2**	**34**
		78	**S:** **48**	**19**	**13**	**120**

A.2
Description of modules

Overview and detailed description

Module-Nr.	Content of module	Semester	Atten-dance	Mandatory/ elective	Workload [h]	L	E	P	Individual study time [h]	Sum	Σ CP
1	***Fundamentals of Materials Science***				***180***						***6,0***
	Fundamental Concepts of Materials Science	1. S	L 3	m	45 + 90	45			90	180	
	Fundamental Concepts of Materials Science (Exercise)	1. S	E 1	m	15 + 30		15		30		
2	***Atomistic Materials Modeling***				***180***						***6,0***
	Atomistic Materials Modeling	1. S	L 2	m	30 + 60	30			60	180	
	Atomistic Materials Modelling (Exercise)	1. S	E 2	m	30 + 60		30		60		
3	***Physics and Technology of Nanomaterials***				**150**						***5,0***
	Physics & Technology of Nanomaterials	1. S	L 2	m	30 + 60	30			60	150	
	Physics & Technology of Nanomaterials (Exercise)	1. S	E 2	m	30 + 30		30		30		
4	***Materials Analysis***				**150**						***5,0***
	Characterization Techniques of Solids	1. S	L 2	m	30 + 75	30			75	150	
	Characterization Techniques of Solids (Exercise)	1. S	E 1	m	15 + 30		15		30		
5	***Functional Materials***				**180**						***6,0***
a	Macromolecular Chemistry / Structure-Property-Relations	1. S	L 2	m	30 + 60	30			60	90	
b	Natural and Synthetic Functional Materials	2. S	L 2	m	30 + 60	30			60	90	
6	***Laboratory course on materials physics and analysis***				**150**						***5,0***
	Materials Physics and Analysis	2. S	P 3	m	45 + 105			45	105	150	

7	***Surface and Interface Analysis***				**150**						***5,0***
	Fundamentals and Applications of Surface and Interface Spectroscopy	2. S	L 2	m	30 + 75	30			75	150	
	Fundamentals and Appl.of Surface and Interface Spectroscopy(Exercise)	2. S	E 1	m	15 + 30		15		30		
8	***Laboratory course on Materials Chemistry and Analysis***				**150**						***5,0***
	Materials Chemistry and Analysis	3. S	P 3	m	45 + 105			45	105	150	
9	***Project based course***				**240**						***8,0***
a	Current Topics in Materials Science	3. S	S 2	m	30 + 60		30		60	90	
b	Project Based Course	3. S	P 5	m	75 + 75			75	75	150	
10	***General Studies***				**150**						***5,0***
	General Studies	3. S	L 2	m	30 + 60	30			60	90	
	General Studies (Exercise)	3. S	E 2	m	30 + 30		30		30	60	
11	***Master thesis***				**900**						***30,0***
a	Master Thesis	4. S	P 20	m	300 + 420			300	420	720	
b	Concluding Colloquium	4. S	S 2	m	30 + 150		30		150	180	

Elective courses

12	***Interface Electrochemistry***				**150**						***5,0***
	Structure and Dynamics at Materials Interfaces and Nanostructures	1. S	L 2	e	30 + 75	30			75	150	
	Structure and Dynamics at Materials Interfaces and Nanostructures (Exercise)	1. S	E 1	e	15 + 30		15		30		
13	***Polymer Analysis***				**150**						***5,0***
	Polymer Analysis	1. S	L 2	e	30 + 75	30			75	150	
	Polymer Analysis (Exercise)	1. S	E 1	e	15 + 30		15		30		
14	***Quantum Chemistry***				**150**						***5,0***
	Quantum Chemistry	1. S	L 2	e	30 + 60	30			60	150	
	Quantum Chemistry (Exercise)	1. S	E 1	e	15 + 45		15		45		
15	***Biomaterials***				**180**						***6,0***
a	Biopolymers and Biointerfaces	1. S	L 2	e	30 + 60	30			60	90	
b	Bioinspired Materials	1. S	L 2	e	30 + 60	30			60	90	
16	***Computational Spectroscopy***				**180**						***6,0***
	Computational Spectroscopy	2. S	L 2	e	30 + 60	30			60	180	
	Computational Spectroscopy (Exercise)	2. S	E 2	e	30 + 60		30		60		
17	***Semiconductor Epitaxy***				**180**						***6,0***
	Semiconductor Epitaxy	2. S	L 2	e	30 + 60	30			60	180	
	Semiconductor Epitaxy (Exercise)	2. S	E 2	e	30 + 60		30		60		
18	***Semiconductor Processing***				**180**						***6,0***

	Processing of Semiconductors	2. S	L 2	e	30 + 60	30			60	180	
	Processing of Semiconductors (Exercise)	2. S	E 2	e	30 + 60		30		60		
19	***Solid-State Materials Chemistry***				**180**						***6,0***
	Inorganic Materials Chemistry	2. S	L 2	e	30 + 90	30			90	180	
	Inorganic Materials Chemistry (Exercise)	2. S	E 1	e	15 + 45		15		45		
20	***Finite Elemente Modeling***				**180**						***6,0***
	Simulation of Materials	2. S	L 2	e	30 + 90	30			90	180	
	Simulation of Materials (Exercise)	2. S	E 1	e	15 + 45		15		45		
21	***Advanced Materials Analysis***				**180**						***6,0***
a	NMR in Materials Science	2. S	L 2	e	30 + 60	30			60	90	
b	Synchrotron Techniques for Materials Science	2. S	L 2	e	30 + 60	30			60	90	
22	***Soft Matter***				**180**						***6,0***
a	Special Polymer Synthesis	2. S	L 2	e	30 + 60	30			60	90	
b	Liquid Crystals	3. S	L 2	e	30 + 60	30			60	90	
23	***Micro Electromechanical Systems***				**180**						***6,0***
	Micro Electromechanical Systems	3. S	L 2	e	30 + 60	30			60	150	
	Micro Electromechanical Systems (Exercise)	3. S	E 2	e	30 + 60		30		30		
24	***Molecular Thermodynamics***				**150**						***5,0***
	Molecular Thermodynamics	3. S	L 2	e	30 + 60	30			60	150	

	Molecular Thermodynamics (Exercise)	3. S	E 1	e	15 + 45		15		45		
25	***Advanced Electron Microscopy***				**180**						***6,0***
	Microscopy and Spectroscopy with Electrons	3. S	L 2	e	30 + 60	30			60	180	
	Microscopy and Spectroscopy with Electrons (Exercise)	3. S	E 2	e	30 + 60		30		60		
26	***Particle Synthesis***				**150**						***5,0***
	Particle Synthesis	3. S	L 2	e	30 + 60	30			60	150	
	Particle Synthesis (Exercise)	3. S	E 1	e	15 + 45		15		45		
27	***Ion Beam Analysis of Materials***				**180**						***6,0***
	Ion Beam Analysis of Materials	3. S	L 1	e	15 + 30	15			30	60	
	Ion Beam Analysis of Materials	3. S	P 2	e	30 + 60			30	60	90	
	Ion Beam Analysis of Materials	3. S	S 1	e	15 + 30		15		30	30	

Notes for description of modules

If separate exams are required for the individual courses of a module (instead of one single exam covering the complete module), then usually the final mark for the module is the average of the individual exam results, weighed with the workloads of the respective courses - unless stated otherwise in the module description.

Fundamental Concepts of Materials Science

Fundamental Concepts of Materials Science

Modul number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
1	180	6	1	WT	1

1 Module structure:

	Course	type	Attendance(h)	Individual study time(h)	Status (m/e)	Group size
a	Fundamental Concepts of Materials Science	L	45	90	P	
b	Fundamental Concepts of Materials Science	S	15	30	P	up to 30

2 Options within the module:

none

3 Participation requirements:

Fundamental knowledge in composition and crystal structure of solids, basic knowledge in thermodynamics.

4 Content of module:

- Real structure of solids and crystal defects
- Diffusion in solids
- Elastic and plastic deformation of solids
- Dislocations and hardening mechanisms
- Aging and fatigue of materials
- Failure mechanisms and prediction
- Binary and ternary phase diagrams
- Phase transitions
- Properties of metals, polymers and ceramic materials
- Structure-property relations of composites
- Fundamentals of tribology

5 Learning outcomes:

In this lecture the students get knowledge of essential and advanced concepts of materials science, based on fundamental physical and chemical concepts. Newcomers with a background in physics or chemistry get to know about the basics of materials science, students with a bachelor in materials science get advanced knowledge in the scientific background of materials science. Therefore in the end, all students will be able to discuss macroscopic materials properties on the basis of fundamental scientific relationships.

The learned contents are adapted to simple problems, of which the results are presented in tutorials, for example by board presentation. By this the students get used to logical argumentation and the skill to represent scientific issues adequately.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	weighting of grade for modul grade
	written or oral examination	120-180 min. 30-45 min.	100 %

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>SL / QT</th></tr><tr><td></td><td></td><td></td><td></td></tr></table>
The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.</td></tr>
<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:</td></tr>
<tr><td>12</td><td>Module coordinator:
Lindner</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
W. D. Callister, D. G. Rethwisch; Materials Science And Engineering, Wiley</td></tr>
</table>

Atomistic Materials Modeling

Atomistic Materials Modeling

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
2	180	6	1st	WS	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Atomistic Materials Modeling	L	30	60	m	
b	Atomistic Materials Modeling	S	30	60	m	up to 30

2 Options within the module:

none

3 Participation requirements:

Elementary Quantum Mechanics

4 Content of module: The lecture gives an overview of the fundamentals necessary for atomistic materials modelling with special emphasis on structural properties and the electronic ground state. Within the exercises: Application of these concepts onto selected problems in the field of solid states, surface, and interfaces; comparison with available experimental data.

- Empirical potentials and force fields
- Electronic exchange and correlation
- Density functional theory
- Wave-function based methods
- Basis sets and pseudopotentials
- Atomic and electronic structure calculations, ab initio thermodynamics

5 Learning outcomes:

The students are able to simulate atomistically materials with standard tools of computational materials science. They know:

- the basic methods of atomistic materials simulation and their typical applications and limitations,
- how to identify suitable methods for modelling molecules, solids, and nano structures,
- how to apply major software packages for atomistic simulations like Gaussian and Quantum Espresso and how to determine meaningful numerical parameters,
- and how to evaluate the outcome of the simulations in the context of data in the scientific literature.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written or oral examination	120-180 or 30-45 minutes	100%

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>SL/QT</th></tr><tr><td></td><td></td><td></td><td></td></tr></table>
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<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing the examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
M.Sc. Physics</td></tr>
<tr><td>12</td><td>Module coordinator:
W.G. Schmidt/Schindlmayr</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
Richard M. Martin, Electronic Structure: Basic Theory and Practical Methods (Cambridge University Press 2008)</td></tr>
</table>

Physics and Technology of Nanomaterials

Physics and Technology of Nanomaterials

Modul number:	**Workload (h):**	**Credits:**	**Semester:**	**Frequency:**	**Duration (in Sem):**
3	150	5	1	WT	1

1 Module structure:

	Course	type	Attendance (h)	Individual study time(h)	status (m/e)	group size
a	Physics and Technology of Nanomaterials	L	30	60	m	
b	Physics and Technology of Nanomaterials	S	30	30	m	up to 30

2 Options within the module:

none

3 Participation requirements:

Fundamental knowledge of composition and crystal structure of solids, fundamentals of thermodynamics and quantum mechanics.

4 Content of module:

- Thermodynamic and crystallographic foundations of nanomaterials
- Preparation of thin films out of fluid phase and vacuum, vacuum physics
- Patterning and modification of thin films using thermal, wet chemical, ion beam assisted and plasma based processes
- Lateral structuring of thin films and surfaces by using conventional and advanced lithography processes
- Preparation, processing and application of 1-, 2- and 3-dimensional nanoobjects (nanowires and tubes, graphene and van-der-Waals materials, nanocluster, core-shell-structures)

5 Learning outcomes:

Knowledge of fundamental methods to prepare modern nanomaterials, their atomistic structure and the resulting physicochemical properties and applications. Understanding of the mathematical formulation of the physical issues and models.

Skills:

Analysing problems dealing with nanomaterials, recognizing problems, referring to the lecture, creating technological concepts, formulating problems mathematically, discussing results and putting them into a materials physics context.

Ability to think conceptually, analytically and logically. Skill to apply the know-how in different sections of materials science and to transfer the knowledge to new materials classes.

Presentation skills due to representing solutions of problems in tutorials. Capacity for teamwork due to handling of problems in small groups.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	weighting of grade for modul grade
	written or oral examination	120 – 180 min. 30-45 min.	100 %

<table>
<tr><td></td><td>The teacher announces the type of examination within the first three weeks.</td></tr>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
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none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
M.Sc. Physics</td></tr>
<tr><td>12</td><td>Module coordinator:
Lindner/Reuter</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
Bharat Bhushan (ed.): Springer Handbook of Nanotechnology
Materials Research Society Bulletin, Selected Issues; Cambridge University Press</td></tr>
</table>

Materials Analysis

Materials Analysis

Modul number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
4	150	5	1.	WT	1

1 Module structure:

	Course	type	Attendance (h)	Individual study time (h)	status (m/e)	group size
a	Characterization Techniques of Solids	L	30	75	P	
b	Characterization Techniques of Solids	E	15	30	P	up to 30

2 Options within the module:

non

3 Participation requirements:

none

4 Content of module:

Ring lecture: microscopic, spectroscopic, electrochemical methods for the characterization of materials: scanning electron microscopy, X-ray-diffraction, X-ray absorption, Rutherford Backscattering Spectroscopy, nuclear magnetic resonance, mass spectroscopy, light scattering, neutron techniques, calorimetric techniques, infrared and Raman spectroscopy, ellipsometry

5 Learning outcomes / Skills:

The students gain an overview on selected modern techniques used to characterize condensed matter. They learn about the right choice to select the appropriate analytical tool in order to study different materials and materials properties. Students obtain fundamental knowledge on these techniques, their limits and applicability, the advantages, disadvantages and costs of individual techniques.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for modul grade
	written or oral examination	120 Min. oder 30 Min.	

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL) / qualifizierte Teilnahme (QT):

	Type	Duration or length	SL / QT

The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.

8 Requirements for participation in an examination:

None

9 Requirement for obtaining credits:

	Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:** M.Sc. Chemie
12	**Module coordinator:** Grundmeier/Lindner
13	**Additional information:** Language english

Functional Materials

Functional Materials

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
5	180	6	1.	a) WT b) ST	2

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Macromolecular Chemistry / Structure-Property-Relations	L	30	60	m	
b	Natural and Synthetic Functional Materials	L	30	60	m	

2 Options within the module:

none

3 Participation requirements:

Basic knowledge of fundamental concepts of material science

a. Basics of analytic of materials

4 Content of module:

- Chain structure in melts and solution (thread end distance, radii of gyration, Theta-solvents, good solvents), Flory-Huggins theory, scaling laws after de Gennes, thermal properties (Tg, Tm) and mechanical properties (visco-elastic behaviour of thermoplastics, thermosets, elastomers, foam), polymer networks.

- The characteristic and applications of organic materials will be discussed: Natural products; ionic liquids; molecular rods, rotators and machinery; organic sensors and electric conductors; fullerenes; carbon nanomaterials; nano-reactors; organic photovoltaic cells

5 Learning outcomes:

The students know:

- a. the basics of polymer physics, and will be capable to apply this knowledge in order to learn independently new correlations and solve problems in the field of polymer physics, to deepen knowledge or optionally also to transfer and apply them.
- b. The lecture will deepen the knowledge and concepts of organic materials. The students will be able allocate more complicated materials and determine their uses.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	One written exam for both lectures	180 min	100%

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
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Passing the examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:</td></tr>
<tr><td>12</td><td>Module coordinator:
Wilhelm</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
a) -P. Flory, Principles of Polymer Chemistry, Cornell University Press 1953;
-I. Teraoka, Polymer Solutions, Wiley-Interscience 2002.
b) -A. Hirsch, M. Brettreich, Fullerenes: Chemistry and Reactions, Wiley-VCH, 2005, Weinheim
-A. Krüger, New Carbonmaterials, Teubner Verlag, 2007, Wiesbaden
-Ionic Liquids in Synthesis, Wasserscheid; Welton, ed. 2. Auflage, 2007, Wiley-VCH, Weinheim</td></tr>
</table>

Laboratory Course on Materials and Analysis

Laboratory Course on Materials and Analysis

Modul number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
6	150	5	2	ST	1

1 Module structure:

	Course	Type	Attendance(h)	Individual study time(h)	Status (m/e)	Group size
	Materials Physics and Analysis	P	45	105	m	up to 7

2 Options within the module:

The students choose three experiments from a list of experiments which are depicted on the internet. The experiments result from the scientific working areas of the research groups involved in the materials science master program.

3 Participation requirements:

none

4 Content of module:

Fundamental analytical methods of material science are explained and adapted to current topics, for example:

- Texture analytics and stress-strain measurements in a scanning electron microscope
- X-ray diffraction of powders or thin films
- Surface wetting and surface free energy
- Computer assisted determination of electron densities
- Molecular beam epitaxy of compound semiconductors
- Ellipsometry of thin films

5 Learning outcomes:

Fundamental knowledge and application of selected methods to characterize advanced functional and structural materials. Adaption of modern methods of data acquisition and computer techniques.

Skills:

Students learn to plan and to implement systematic experiments for materials characterization with respect to macroscopic properties in real laboratories, and to document and to analyze the results. By critically evaluating their own data and comparing them to known and published data of other groups, the students get the competence to classify the results concerning reliability and validity. By recording the results, the students get competence of presentation in writing, and they get prepared to writing scientific papers. Students improve their capacity for teamwork by solving problems in small groups.

6 Degree-relevant examination(s):

[] Final module examination (MAP) [x] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for modul grade
	Total number of experiments	3	100%

<table>
<tr><td></td><td>The teacher announces the type of examination within the first three weeks.</td></tr>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
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none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
Single experiments are also elements in modules of following courses: Chemistry M.Sc., Physics M.Sc., Chemieingenieurwesen M.Sc., Optoelectronics & Photonics M.Sc., Light weight construction, Maschinenbau</td></tr>
<tr><td>12</td><td>Module coordinator:
Lindner/Grundmeier</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
</table>

Surface and Interface Analysis

Surface and Interface Analysis

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
7	150	5	2.	ST	1

1 Module structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
a	Fundamentals and Applications of Surface and Interface Spectroscopy	L	30	75	m	
b	Fundamentals and Applications of Surface and Interface Spectroscopy	E	15	30	m	up to 30

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

Optical spectroscopy of materials interfaces and thin films (by ellipsometry, FTIR- and Raman-spectroscopy); photoelectron-based and ion-spectroscopy of surfaces and thin films (Auger spectroscopy, X-ray and UV-photoelectron spectroscopy, ion scattering); advanced applications of spectroscopy (combined characterization methods, in-situ spectroscopy, spectroscopic microscopy, spectroscopic electrochemistry).

5 Learning outcomes:

The students learn about the most common spectroscopic methods employed for the characterization of surfaces and interfaces in materials research.

In detail, students will learn

- to determine which surface characterization methods are appropriate for different kinds of materials
- to critically evaluate the results of the measurements
- to develop measurement strategies using combination of different methods, according to the challenges presented by the materials to be characterized
- to apply such spectroscopic methods for in-situ analysis of processes at interfaces.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written or oral examination	120 min. or 30 min.	100 %

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL / QT

	<table><tr><td></td><td></td><td></td><td></td></tr></table> The teacher announces the type of examination within the first three weeks.
8	**Requirements for participation in the examination:** none
9	**Requirement for obtaining credits:** Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:** M.Sc. Chemistry
12	**Module coordinator:** Grundmeier
13	**Additional information:** Language english
14	**Recommended literature:** Modern Spectroscopy, J. M. Hollas, John Wiley & Sons, 2004. Low Energy Electrons and Surface Chemistry, G. Ertl and J. Küppers, VCH, 1985 Practical Surface Analysis I and II, D. Briggs and M. P. Seah, John Wiley & Sons, 1990 Surface Infrared and Raman spectroscopy –methods and applications, W. Suetaka, Plenum Press 1995

Laboratory Course on Materials Chemistry and Analysis

Laboratory Course on Materials Chemistry and Analysis

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
8	150	5	3	WT	1

1 Module structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
	Materials Chemistry and Analysis	P	45	105	m	up to 6

2 Options within the module:

Students will have a choice of three experiments from a given list, which will be published online. The experiments originate from the scientific areas of the Departments involved in the Master.

3 Participation requirements:

none

4 Content of module:

Different basic characterization methods will be introduced and used to address current scientific questions, such as for example:

- Spectroscopy of surfaces and interfaces
- Methods of scanning microscopy
- Molecular adsorption at the surface of porous materials
- Synthesis of nanoparticles
- Sol-Gel-methods
- Synthesis and characterization of polymer hybrid materials
- Polymer synthesis by additive methods
- NMR on solids

5 Learning outcomes:

The students will learn the basics and an overview about the modern methods for characterization of solid function- and structure-materials. Application of modern data acquisition methods and computer techniques.

Skills:

Students learn and deepen their capabilities to plan and structure experiments oriented to the determination of the macroscopic characteristics of a material, to implement the plan within a real laboratory environment, and to document and evaluate their results. The critical evaluation of their measurement data and comparison with existing published knowledge will give them the critical skills necessary to evaluate the quality and reliability of other measurements. From having to document and protocol their results, students learn to handle the actual documentation of scientific results. Finally, they improve their team working by addressing the solution of specific questions in small groups

6 **Degree-relevant examination(s):**

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written report of each of the three experiments	About 10 pages per report	100 %

The teacher announces the type of examination within the first three weeks.

7 **Required coursework (SL)/qualifizierte Teilnahme (QT):**

	Type	Duration or length	SL / QT

The teacher announces the type of examination within the first three weeks.

8 **Requirements for participation in the examination:**

none

9 **Requirement for obtaining credits:**

Passing of final module examination

10 **Weighting of module grade in calculation of final overall grade:**

The module will be weighted with the number of its credit points (factor: 1)

11 **This module is also an element of the following degree programmes:**

Individual Experiments will be also validated for other Modules: Chemistry M.Sc., Physics M.Sc., Chemieingenieurwesen M.Sc., Optoelectronics & Photonics M.Sc.; ILH, Maschinenbau.

12 **Module coordinator:**

Grundmeier/Lindner

13 **Additional information:**

Language English

14 **Recommended literature:**

The Science and Engineering of Materials, D. R. Askeland et al., Cengage Learning, Inc., 2015

Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Y. Leng, Wiley-VCH, 2013

Characterization of Amorphous and Crystalline Rough Surface -- Principles and Applications, Y. Zhao et al., Academic Press, 2000.

Low Energy Electrons and Surface Chemistry, G. Ertl and J. Küppers, VCH, 1985

Practical Surface Analysis I and II, D. Briggs and M. P. Seah, John Wiley & Sons, 1990

Project based Course

Project based Course

Module number:	Workload (h):	Credits:	Semester:	Turnus:	Duration (in Sem):
9	240	8	3	WT	1

1 Module structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
a	Current Topics in Materials Science	S	30	60	P	
b	Project based Course	P	75	75	WP	up to 6

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

These project courses will be integrated within the actual research topics of the involved departments. The involved Professors will assume both the supervision and the topic assignment. The students will have the opportunity to develop real scientific research skills by concentrating in specific experiments related to actual ongoing research. This involves learning to perform literature research appropriate to the topic, and training in the necessary experimental setups.

5 Learning outcomes:

- Students will learn to present their results about current research in an oral presentation. That covers not only the methodology employed but also the total scientific process of problem-solving. The goal is to learn how to communicate scientific results in an effective way.
- Students will learn how to plan and organize a small scientific project in an interdisciplinary environment, which also will give them the opportunity to learn how to work in a real working team.
- Students will prepare a final written report in which they will learn how to display and analyze their experimental results in a clear and above all, critical way, and how to communicate their results effectively

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a	Seminar	30-45 min.	37,5%
b	Written report	Max. 50 pages	62,5,%

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

		Type	**Duration or length**	**SL / QT**

The teacher announces the type of examination within the first three weeks.

8	**Requirements for participation in an examination:** none
9	**Requirement for obtaining credits:** Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:**
12	**Module coordinator:** Grundmeier/Lindner
13	**Additional information:** Language english
14	**Recommended literature:** Recommended individually according to chosen topic (mainly articles published in peer reviewed journals).

General Studies

General Studies

Module number:	Workload (h):	Credits:	Semester:	Turnus:	Duration (in Sem):
10	150	5	3	WT	1

1 Module structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
	Depends on the student's choice between the offers published at the Campus Management System				m	

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

The available activities will be published in the Campus Management System of the Paderborn University.

5 Learning outcomes:

Depending on the actual choice, key qualifications such as foreign languages, etc.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written or	120 min.	100 %
	oral examination	30 min.	

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL / QT

The teacher announces the type of examination within the first three weeks.

8 Requirements for participation in an examination:

none

9 Requirement for obtaining credits:

	Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:**
12	**Module coordinator:** Grundmeier/Lindner
13	**Additional information:** Language English
14	**Recommended literature:** Recommended individually according to chosen courses

Master Thesis

Master Thesis

Module number:	Workload (h):	Credits:	Semester:	Turnus:	Duration (in Sem):
11	900	30	4	ST	1

1 Module structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
a	Master Thesis	P	300	420	m	
	Concluding Colloquium	S	30	150	m	

2 Options within the module:

none

3 Participation requirements:

Completion of all previous modules

4 Content of module:

The topic is chosen from the projects offered by the Departments involved in the Master Course.

5 Learning outcomes:

By the completion of the Master thesis, the students prove that they are able to address the scientific approach to problem-solving within a specific given field, and to recapitulate their results and analysis in the form of a written report.

They will improve their knowledge in working procedures through practical work and literature research. Handling the scientific literature, typically written in English, foreign language skills will be improved. By working and developing their own project, students will learn to work independently, improve their planning abilities and creativity. The integration within an actual working group will develop their team working skills.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a	Written master thesis	5 Months	
b	oral concluding colloquium	30-45 min.	

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL / QT

	The teacher announces the type of examination within the first three weeks.
8	**Requirements for participation in an examination:** none
9	**Requirement for obtaining credits:** Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:**
12	**Module coordinator:** Grundmeier/Lindner
13	**Additional information:** Language English
14	**Recommended literature:** Recommended individually according to chosen topic

Interface Electrochemistry

Interface Electrochemistry

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
12	150	5	1	WT	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
a	Structure and Dynamics at Materials Interfaces and Nanostructures	L	30	75	e	
b	Structure and Dynamics at Materials Interfaces and Nanostructures	E	15	30	e	up to 30

2 Options within the Module:

none

3 Participation requirements:

none

4 Content of module:

Advanced electrochemical theories, semiconductor electrochemistry, electrocatalysis, advanced electrochemical analysis, chemistry and electrochemistry of interfaces for energy applications, interface processes for surface applications, corrosion of metals and adhesives, bioelectrochemistry and biosensors.

5 Learning outcomes:

The students will gain detailed knowledge of

- the theoretical description of electron transfer reactions
- semiconductor electrodes
- electrocrystallization and the mechanisms of metal deposition and dissolution
- the electrochemical deposition of thin films and nanostructures
- the corrosion of metals and approaches toward corrosion inhibition and passivation
- DNA-mediated electrochemistry
- electrochemical biosensors

They will furthermore learn about common and specialized electrochemical methods such as cyclic voltammetry, electrochemical impedance spectroscopy, rotating disk electrode, etc. They will be able to perform such electrochemical experiments, analyze the data and interpret the results with regard to the fundamental molecular mechanisms involved.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written or oral examination	120 min. or 30 min.	100 %

The teacher announces the type of examination within the first three weeks.

7 **Required coursework (SL)/qualifizierte Teilnahme (QT):**

zu	Type	Duration or length	SL / QT

The teacher announces the type of examination within the first three weeks.

8 **Requirements for participation in an examination:**
none

9 **Requirement for obtaining credits:**
Passing of final module examination

10 **Weighting of module grade in calculation of final overall grade:**
The module will be weighted with the number of its credit points (factor: 1)

11 **This module is also an element of the following degree programmes:**

12 **Module coordinator:**
Grundmeier/Lindner

13 **Additional information:**
Language english

14 **Recommended literature:**

Electrochemistry, C. H. Hamann et al., Wiley-VCH, 2007

Interfacial Electrochemistry, W. Schmickler et al., Springer, 2014;

Surface Electrochemistry: A Molecular Level Approach, John O'M. Bockris_and Shahad U.M. Khan, Springer 2013

Bioelectronics - From Theory to Applications, I. Willner et al., eds., WILEY-VCH 2005;

Bioelectrochemistry - Fundamentals, Experimental Techniques and Applications, P. N. Bartlett, ed, John Wiley & Sons Ltd, 2008

Polymer Analysis

Polymer Analysis

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
13	150	5	1	WT	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Polymer Analysis	L	30	90	e	
b	Polymer Analysis	E	15	45	e	up to 30

2 Options within the module:

none

3 Participation requirements:

Basic knowledge in Polymer chemistry. Fundamental principles of physical chemistry.

4 Content of module:

Chemical characterization via spectroscopy of charged particles (ESCA , Auger electron and SIMS), via spectroscopy of electromagnetic waves (IR and NMR-spectroscopy); determination of molar mass (GPC, ultracentrifuge, mass spectrometry, colligative properties and light scattering); analytics of polymeric structures with NMR (tacticity) and with scattering techniques (size, shape and structure factor).

5 Learning outcomes:

The students know:

an overview on relevant analytical techniques and methods in polymer and colloid science and will be enabled to select adequate analytical tools and methods for solving standard problems in polymer and colloid characterization and analysis.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written examination	120 minutes	100 %

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL/QT

The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.

8 Requirements for participation in an examination:

none

9 Requirement for obtaining credits:

	Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:** M.Sc. Chemistry
12	**Module coordinator:** Huber
13	**Additional information:** Language english
14	**Recommended literature:** Sohár, P. Nuclear Magnetic Resonance Spectroscopy (Volume I, CRC Press) Rubinstein, M.; Colby, R. Polymer Physics (Oyford University Press) Mark, H. (ed.) Encyclopedia of Polymer Science and Engineering (Wiley) Kroschwitz, J. (ed.) Encyclopedia of Polymer Science and Technology (Wiley)

Quantum Chemistry

Quantum Chemistry

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
14	150	5	1.	WT	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Quantum Chemistry	L	30	60	e	
b	Quantum Chemistry	E	15	45	e	Up to 30

2 Options within the module:

none

3 Participation requirements:

Basis knowledge of quantum mechanics

4 Content of module:

The lecture gives an overview of the fundamentals necessary for a theoretical description of chemical systems in the gas and condensed phase. Special emphasis is given onto concepts and state-of-the-art strategies of their numerical determination. *Within the exercises*: Application of these concepts onto selected problems in the field of molecular, solid state and surface chemistry.

- Born-Oppenheimer approximation,
- Electronic Schrödinger equation
- Basis set representation of wave functions
- Density functional theory
- Ab-initio molecular dynamics
- Hartree-Fock
- Electron correlation
- Configuration-interaction
- Coupled-cluster
- Quantum Monte Carlo.

5 Learning outcomes:

The students become familiar with the basic concepts of computational and theoretical chemistry. They will be able to apply these concepts for a numerical prediction to be compared with available experimental data.

In detail, the students

- Know advanced theoretical quantum chemistry methods
- Are able to apply them to solve relevant questions of chemistry, physics and materials science by means of computer simulations.

<table>
<tr><td>6</td><td>Degree-relevant examination(s):
[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>Weighting of grade for module grade</th></tr><tr><td></td><td>Written or oral examination</td><td>120 or 30-45 minutes</td><td>100%</td></tr></table>
The teacher announces the type of examination within the first three weeks.</td></tr>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
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The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.</td></tr>
<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing the examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:</td></tr>
<tr><td>12</td><td>Module coordinator:
Kühne</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
</table>

Biomaterials

Biomaterials

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
15	180	6	1	WT	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time (h)	Status (m/e)	Group-size
a	Biopolymers & Biointerfaces	L	30	60	e	
b	Bioinspired Materials	L	30	60	e	

2 Options within the Module:

none

3 Participation requirements:

none

4 Content of module:

a. Protein structure, membrane systems, membrane proteins, protein adsorption, protein aggregation, DNA- and RNA-structure, self-assembled DNA monolayers, DNA-nanotechnology.

b. Molecular composition of biomaterials, biomaterials for medicine, biological composite materials, bionics in materials science, modern methods for materials characterization.

5 Learning outcomes:

Students gain:

a. Deeper understanding about structure of biomolecules, interactions of biomolecules with biological and artificial interfaces, and biomolecular self-assembly, as well as the resulting possible applications within the areas of material research, sensing, and nanotechnology.

b. Fundamental knowledge about the most typically used methods for materials characterization. Deeper understanding about the chemical and molecular aspects of biomaterials, and their medical applications. Understanding of the concept of hierarchically built materials by looking at examples from the natural world. Understanding of the principles of bionics and their applicability in materials science, including the physical and chemical backgrounds.

6 Degree-relevant examination(s):

[] Final module examination (MAP) [] Module examination (MP) [x] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a	Seminar	15 min	50%
b	Seminar	15 min	50%

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL / QT

	The teacher announces the type of examination within the first three weeks.
8	**Requirements for participation in the examination:** none
9	**Requirement for obtaining credits:** The credits will be awarded after the corresponding exams have been passed.
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:**
12	**Module coordinator:** Grundmeier
13	**Additional information:** Language English
14	**Recommended literature:** Molecular Cell Biology, Fifth Edition, H. Lodish et al., Palgrave Macmillan, 2004; BIOMATERIALS SCIENCE - An Introduction to Materials in Medicine, B. D. Ratner et al., eds.,Academic Press, 1996; BIONANOTECHNOLOGY - Lessons from Nature, D. S. Goodsell, Wiley-Liss, Inc., 2004; Applied Biophysics - A Molecular Approach for Physical Scientists, T. A. Waigh, John Wiley & Sons Ltd, 2007; Understanding DNA. The Molecule and How It Works, C. R. Calladine et al., Academic Pr Inc, 2004; Biopolymers at Interfaces, Second Edition, M. Malmsteen, Marcel Dekker Inc., 2003; DNA Topology, A. D. Bates et al., OUP Oxford, 2005

Computational Spectroscopy

Computational Spectroscopy

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
16	180	6	2nd	SS	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
	Computational Spectroscopy	L	30	60	e	
	Computational Spectroscopy	E	30	60	e	up to 30

2 Options within the module:

none

3 Participation requirements:

Elementary Quantum Mechanics

4 Content of module:

The lecture gives an overview of the fundamentals necessary for a theoretical description of spectroscopic properties of modern materials. Special emphasis is given onto concepts and state-of-the-art strategies of their numerical determination. *Within the exercises*: Application of these concepts onto selected problems in the field of molecular, solid state and surface physics; comparison with available experimental data.

- fundamental basics: time-dependent perturbation theory, Fermi's Golden Rule, linear response, Berry's phases, quasi-particle excitations,
- infrared (IR) and Raman spectroscopy,
- linear and non-linear optical spectra,
- XPS – core level spectroscopy,
- X-ray absorption: XAS, XANES, (N)EXAFS,
- circular dichroism (XMCD),
- magnetic resonance (NMR and EPR),
- electron transport, photo currents,
- imaging spectroscopy (STM and AFM).

5 Learning outcomes:

The students become familiar with the basic concepts of computer-assisted calculation (simulation) of spectroscopic properties of new materials. They will be able to apply these concepts for a numerical prediction to be compared with available experimental data.

In detail, the students

- are able to identify and to analyse relevant problems in the context of spectroscopic analysis of materials,
- are aware of the fact that modern spectroscopic experiments can often only be analysed to full extend with comparative theoretical data,
- know the basic quantum mechanical strategies and computational concepts required for a microscopic simulation of materials and for a prediction of their spectroscopic properties,
- are able to choose adequate levels of description and approximation for a given problem (by

<table>
<tr><td></td><td>carefully weighting numerical costs vs. accuracy) and can apply corresponding methods,
▪ are able to discuss the obtained theoretical data in the context of experimental data and can correlate them with modern problems in materials science.</td></tr>
<tr><td>6</td><td>Degree-relevant examination(s):
[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>Weighting of grade for module grade</th></tr><tr><td></td><td>Written or
oral examination</td><td>120-180
30-45 minutes</td><td>100 %</td></tr></table>
The teacher announces the type of examination within the first three weeks.</td></tr>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
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The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.</td></tr>
<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1).</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
M.Sc. Physics</td></tr>
<tr><td>12</td><td>Module coordinator:
Gerstmann/Schindlmayr</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
</table>

Semiconductor Epitaxy

Semiconductor Epitaxy

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
17	180	6	2.	ST	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Semiconductor Epitaxy	L	30	60	e	
b	Semiconductor Epitaxy	E	30	60	e	Up to 30

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module: Basics

Basics of crystal structures

Elastic properties of heterostructures

Dislocations

Thermodynamics of layer growth

Equilibrium states

Crystal growth

Atomistic aspects of layer growth

Surface structure

Kinetic processes during layer growth

Self-organized nanostructures

Methods of Semiconductor epitaxy

Molecular beam Epitaxy(MBE)

Metal organic vapour-phase epitaxy

Methods of Characterization

In-situ analytical methods (RHEED)

High-resolution x-ray diffraction (HRXRD)

5 Learning outcomes:

The students acquire:

Specialised skills:

Lecture: Knowledge of fundamental concepts of semiconductor epitaxy including aspects of fabrication, properties, characterization. Insight into and possibly mathematical formulation of physical facts and models.

Exercise: Solving questions regarding semiconductor epitaxy with practical perspective using the knowledge gained from lectures. Identifying arising problems, establishing reference to the lectures, possibly formulating problems mathematically, discussing results and placing them in a broader physical

<table>
<tr><td></td><td>context.
Multidisciplinary competences:
Ability to think conceptually, analytically and logically and the competence to make use of the acquired knowledge in different fields of semiconductor nanostructure physics.
Ability to adopt the trained problem-solving strategies in a cross-functional way.
Presentation skills by showing effective solutions as part of the exercise.
Ability to deepen the gained competences in self-study.
Showing team spirit by cooperative problem- solving in small groups.</td></tr>
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The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks. (qualified participation?)</td></tr>
<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing the examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
Master Physics</td></tr>
<tr><td>12</td><td>Module coordinator:
Reuter/As</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
“Epitxaxy of Semiconductors”, Udo W. Pohl (Springer Heidelberg 2013)</td></tr>
</table>

Semiconductor Processing

Semiconductor Processing

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
18	180	6	2.	SS	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Processing of Semiconductors	L	30	60	e	
b	Processing of Semiconductors	E	30	60	e	up to 30

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

Equipment, processes and techniques for processing of Silicon semiconductor

- Crystal growth, oxidation, lithography
- Etching, doping, layer deposition, contacts
- Wafer cleaning, CMOS processing
- Discussion of the processes, modelling and equipment types will be discussed

Exercises to deepen the contents of the lecture will be offered to the students

5 Learning outcomes:

The students are able to describe:

- The production of silicon wafers and the processes up to the integration of CMOS circuits
- The individual process steps and the combination of the processes to integrate a device
- To develop a process to get the requested structures in silicon

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written examination	60 min.	100%

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL/QT

The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.

8 Requirements for participation in an examination:

	None
9	**Requirement for obtaining credits:** Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted by the number of its credit points (factor 1)
11	**This module is also an element of the following degree programmes:** The module is part of the Master programme in Electrical Systems Engineering
12	**Module coordinator:** Hilleringmann
13	**Additional information:** Language english
14	**Recommended literature:** S. M. Sze: VLSI technology R. Doering, Y. Nishi: Semiconductor Manufacturing Technology, CRC Press

Solid-State Materials Chemistry

Solid-State Materials Chemistry

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
19	180	6	2	ST	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Inorganic Materials Chemistry	L	30	90	e	
b	Inorganic Materials Chemistry	E	15	45	e	up to 30

2 Options within the module:

none

3 Participation requirements:

Basic knowledge of chemical synthesis and solid-state chemistry

4 Content of module:

- solid-state structures and symmetry
- functional materials (e.g. silica, metal oxides, hybrid materials)
- sol-gel synthesis, ceramics, biominerals, special processes in materials synthesis
- selected classes of materials (e.g. porous materials)
- analytical methods (e.g. X-ray diffraction, physisorption, thermal analysis)

5 Learning outcomes:

The students

- are familiar with modern concepts of chemical synthesis for inorganic functional materials and with relevant characterization techniques.
- understand structure-property relationships
- are able to conceive synthesis strategies for materials with desired function and to design defined product properties
- know how to apply synthesis/characterization methods to selected problems from laboratory practice
- learn how to critically evaluate and assess original scientific literature

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written or oral examination	60 minutes 30 minutes	100 %

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
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none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
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<tr><td>11</td><td>This module is also an element of the following degree programmes:
M.Sc. Chemie</td></tr>
<tr><td>12</td><td>Module coordinator:
Tiemann</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
L. E. Smart, E. A. Moore: Solid State Chemistry; U. Schubert, N. Hüsing: Synthesis of Inorganic Materials</td></tr>
</table>

Finite Elemente Modeling

Finite Elemente Modeling

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
20	180	6	2.	SS	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Simulation of Materials	L	30	90	e	
b	Simulation of Materials	E	15	45	e	up to 30

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

- Introduction to non-linear material behavior
- Constitutive equations of elasto plasticity
- Constitutive equations of visco plasticity
- Constitutive equations of visco elasticity
- Numerical integration
- Non-linear finite element formulation

5 Learning outcomes:

The students know:

- Characteristics of elasto plastic, visco plastic and viso elastic materials
- Rheological models
- Constitutive modeling of material behavior
- Multidimensional flow functions
- Numerical implementation in MATLAB
- Simulation of applications in the commercial finite element program Abaqus

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Oral examination	30 min	100%

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL/QT

	The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.
8	**Requirements for participation in an examination:** none
9	**Requirement for obtaining credits:** passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted with the number of its credit points (factor: 1)
11	**This module is also an element of the following degree programmes:**
12	**Module coordinator:** Mahnken
13	**Additional information:** Language english

Advanced Materials Analysis

Advanced Materials Analysis

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
21	120	6	2	SS	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	NMR in Materials Science	L	30	60	WP	
b	Synchrotron Techniques for Materials Science	L	30	60	WP	

2 Options within the module:

none

3 Participation requirements:

a. Basic knowledge of quantum mechanics and spectroscopy

b. Basic knowledge of quantum mechanics and spectroscopy

4 Content of module:

a. FT NMR, multidimensional spectroscopy, relaxometry, diffusometry and imaging with examples of applications, primarily from the field of soft matter and noncrystalline materials

b. x-ray methods: x-ray absorption (XAS), x-ray emission (XES), resonant inelastic x-ray scattering (RIXS), Nuclear inelastic scattering and related methods, x-ray diffraction (XRD), pair distribution analysis (PDF), x-ray photoelectron spectroscopy (XPS), x-ray dichroism (XMCD); other methods: infrared spectroscopy, UV circular dichroism.

Optional excursion of one to two days to the PETRA III synchrotron in Hamburg.

In both interactive courses seminar-like problem sessions will be used to study details of the methods and discuss given exercises.

5 Learning outcomes:

The students know:

a. the physical basics of magnetic resonance, how to read and understand the literature in the field, and how to design magnetic resonance applications for the determination of structure and dynamics in materials science,

b. the analytical and spectroscopic possibilities at a syncrotron, the functioning of a synchrotron and the theoretical basics of the methods, how to use the methods to specific questions in materials science, and how to decide which methods are suitable for different types of problems.

A possible excursion (depending on time slots at the synchrotron) to the PETRA III synchrotron makes the students on-site familiar with the specifics of a large-scale instrument and allows to solidify their theoretical knowledge of the experiments at the instrument.

6 **Degree-relevant examination(s):**

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a), b)	joint oral exam	30-45 min	100 %
	or		
a), b)	joint written exam	120 min	100 %

The teacher announces the type of examination within the first three weeks.

7 **Required coursework (SL)/qualifizierte Teilnahme (QT):**

	Type	Duration or length	SL/QT

The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.

8 **Requirements for participation in an examination:**

none

9 **Requirement for obtaining credits:**

Credits will be given if the final module examination is passed.

10 **Weighting of module grade in calculation of final overall grade:**

The module grade is weighted by the number of credits (factor 1).

11 **This module is also an element of the following degree programmes:**

The courses of this module are used in the M. Sci. in Chemistry programme.

12 **Module coordinator:**

C. Schmidt

13 **Additional information:**

Language of teaching: English

14 **Recommended literature:**

a. Textbooks on NMR, for instance,
M. H. Levitt, "Spin dynamics“, Wiley, 2008.
J. Keeler, "Understanding NMR spectroscopy“, Wiley, 2010 (A video series of 15 lectures by the author is available on www.youtube.com, search for keeler lectures).

b. G. Bunker, “Introduction to XAFS: A practical guide to X-ray absorption fine structure spectroscopy”, Cambridge University Press, Cambridge, 2010.
Frank de Groot, Akio Kotani, „Core level spectroscopy of solids“, CRC Press, Taylor & Francis Group, 2008.

Soft Matter

Soft Matter

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
22	180	6	**2. + 3**	a)SS + b)WS	2

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Special Polymer Synthesis	L	30	60	e	
b	Liquid Crystals	L	30	60	e	

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

a. modern methods of polymer synthesis, synthesis of polymers for specials applications and methods for the elucidation of structure properties relationship

b. classification of liquid crystals, calorimetry and X-ray structure analysis, magnetic, electric and optical anisotropy, elasticity, Euler-Lagrange-Equation and torque balance as well as its application to liquid crystals

5 Learning outcomes:

The students know:

a. Students are able to see the acquired knowledge in organic and macromolecular chemistry related and apply aspects in the field of structurally complex, functional organic materials. These include knowledge of both the synthesis of these materials as well as on the correlations between on the one hand the chemical, physical and morphological structure and on the other hand the profile of properties of the functional materials.

b. Students know ordered liquids and their characterization, anisotropic electrical and optical as well as elastic properties, statics and dynamics of the switching behavior of liquid crystal displays

6 Degree-relevant examination(s):

[] Final module examination (MAP) [] Module examination (MP) [x] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a	Oral examination	45 min.	50%
b	Written examination	120 min.	50%

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>SL/QT</th></tr><tr><td></td><td></td><td></td><td></td></tr></table>
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<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing the examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:</td></tr>
<tr><td>12</td><td>Module coordinator:
Kuckling / Kitzerow</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
Y. Gnanou, M. Fontanille, Organic and Physical Chemistry of Polymers, Wiley-Interscience
H. Stegemeyer, Liquid Crystals, Steinkopff-Springer</td></tr>
</table>

Micro Electromechanical Systems

Micro Electromechanical Systems

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
23	180	6	3.	WS	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Micro Electromechanical Systems	L	30	60	e	
b	Micro Electromechanical Systems	E	30	60	e	up to 30

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

- Processing of Silicon
- Modelling of microsensors
- Characteristics of sensor systems and aktuators in bulk- and surface micromechanics
- Pressure, acceleration, angular rate, flow, tilt sensors
- Valves, relais, actuators

Exercises to deepen the contents of the lecture will be offered to the students

5 Learning outcomes:

The students are able to describe:

- The integration of micro electromechanical devices
- The behaviour of the individual sensor and actuator devices according to mathematical models
- Requests to a sensor system for a given application

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
	Written examination	60 minutes	100%

The teacher announces the type of examination within the first three weeks.

7 Required coursework (SL)/qualifizierte Teilnahme (QT):

	Type	Duration or length	SL/QT

The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.

8 Requirements for participation in an examination:

None

9	**Requirement for obtaining credits:** Passing of final module examination
10	**Weighting of module grade in calculation of final overall grade:** The module will be weighted by the number of its credit points (factor 1)
11	**This module is also an element of the following degree programmes:** The module is part of the Master programme in Electrical Systems Engineering
12	**Module coordinator:** Hilleringmann
13	**Additional information:** Language english
14	**Recommended literature:** T. R. Hsu: MEMS Packaging, INSPEC, 2004 M. Köhler: Etching in Microsystem Technology, Wiley-VCH, 1999 W. Elwenspoek, R. Wiegerink: Mechanical Microsensors, Springer, 2000

Molecular Thermodynamics

Molecular Thermodynamics

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
24	150	5	3.	WT	1

1 Module Structure:

	Course	Type	Attendance (h)	Individual study time(h)	Status (m/e)	Group size
a	Molecular Thermodynamics	L	30	45	e	
b	Molecular Thermodynamics	E	15	30	e	up to 30
c	Seminar Talk	E	5	25	e	

2 Options within the module:

none

3 Participation requirements:

Basic knowledge of thermodynamics

4 Content of module:

The lecture gives an introduction to statistical thermodynamics and how macroscopic properties can be obtained from microscopic molecular interactions by molecular simulations.

- Models of intermolecular interactions: hard-sphere, square-well, Lennnard-Jones potential and electrostatic potentials.
- Fundamentals of molecular simulation: periodic boundary conditions, minimum image convention, cutoff radii, Long-range corrections.
- Simulation methods: molecular dynamics and Monte Carlo.
- Thermodynamic properties from molecular simulation: Ensembles, partition function, state variables from derivatives of the partition function.
- Pair correlation function as a structural feature.
- Specific methods for the calculation of phase equilibria.

5 Learning outcomes:

The students

- Know common approaches to modelling and parameterization of various molecular interactions.
- Have an overview of the basic simulation methods and the foundations of statistical mechanics.
- Can apply the methods and know how to calculate different fluid properties.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a,b	Oral examination	30 – 45 min.	100 %

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
<table>
<tr><th></th><th>Type</th><th>Duration or length</th><th>SL/QT</th></tr>
<tr><td>c</td><td>Seminar-talk to an exemplary topic in the field of molecular thermodynamics</td><td>30 min.</td><td>SL</td></tr>
</table>
The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.</td></tr>
<tr><td>8</td><td>Requirements for participation in an examination:
Course achievement (according to Nr. 7)</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing the examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
Master of mechanical engineering, chemical engineering, industrial engineering</td></tr>
<tr><td>12</td><td>Module coordinator:
Vrabec</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
Toda, M., Kuo, R. und Saito, N.: Statistical Physics I, Equilibrium Statistical Mechanics, Band 30, Springer-Verlag, Berlin, 1983.
Allen, M.P. and Tildesley, D.J.: Computer simulation of liquids. Clarendon Press, Oxford, 1990.
Frenkel, D. and Smit, B.: Understanding Molecular Simulation: From Algorithms to Applications. Academic Press, San Diego, 2002.</td></tr>
</table>

Advanced Electron Microscopy

Advanced Electron Microscopy

Modul number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
25	180	6	3	WT	1

1 Module structure.:

	Course	Type	Attendance(h)	Individual study time(h)	Status (m/e)	Group size
a	Microscopy and Spectroscopy with Electrons	L	30	60	e	
b	Microscopy and Spectroscopy with Electrons	S	30	60	e	up to 30

2 Options within module:

none

3 Participation requirements:

Intimate knowledge of the atomic structure of crystalline solids and quantum mechanics.

4 Content of module:

Fundamental knowledge of transmission electron microscopy and its applications to characterize materials on the nano- and sub-nanometer scale.

- Electron optical components and beam path in a (scanning) transmission electron microscope (S)TEM
- TEM sample preparation
- Imaging techniques and types of contrasts
- Electron diffraction
- Electron-solid-interaction
- Kinematic and dynamic theory of electron diffraction
- Conventional electron microscopy and lattice defects
- Contrast transfer and high-resolution
- Energy dispersive X-ray spectroscopy (EDS)
- Electron energy loss spectoscopy EELS in TEM and STEM
- Spectroscopy of inter and intra gap transitions as well as plasmons
- Energy filtered transmission electron microscopy EFTEM
- In-situ and cryo-methods

5 Learning outcomes:

Proficiency of fundamental concepts of conventional, high-resolution and analytical transmission electron microscopy, from the fundamental knowledge of electron solid interactions and electron diffraction to the resulting contrast mechanisms allowing to characterize crystalline structures, the chemical composition and electronic excitations of solids.

The knowledge is adapted to selected relevant problems in tutorials as well as practical exercises and ranged into the overall physics context.

Skills:

- Conceptual analytical and logical thinking and the know-how to adapt the knowledge to different

<table>
<tr><td></td><td>fields of materials science
• Presantation skills throughout presenting solutions in tutorials
• Teamwork capabilities by working on problems in small groups.</td></tr>
<tr><td>6</td><td>Degree-relevant examination(s):
[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>weighting of grade for modul grade</th></tr><tr><td></td><td>written or
oral examination</td><td>120 - 180 min.
30 - 45 min.</td><td>100 %</td></tr></table>
The teacher announces the type of examination within the first three weeks.</td></tr>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
<table><tr><th></th><th>Type</th><th>Duration or length</th><th>SL / QT</th></tr><tr><td></td><td></td><td></td><td></td></tr></table>
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<tr><td>8</td><td>Requirements for participation in an examination:
none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
The module will be weighted with the number of its credit points (factor: 1)</td></tr>
<tr><td>11</td><td>This module is also an element of the following degree programmes:
Physics MSc.</td></tr>
<tr><td>12</td><td>Module coordinator:
Lindner</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
David B. Williams, C. Barry Carter; Transmission Electron Microscopy: A Textbook for Materials Science; Springer</td></tr>
</table>

Particle Synthesis

Particle Synthesis

Module number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem.):
26	150	5	3.	WS	1

1 Module Structure:

	Lehrveranstaltung	Type	Attenontakt-zeit (h)	Individual study time (h)	Status (m/e)	Group size
a)	Particle Synthesis	L	30	45	WP	
b)	Particle Synthesis	E	15	30	WP	up to 30
c)	Seminar Talk	E	5	25	WP	

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

a. Elementar-processes for particles synthesis (supersaturation, nucleation, growth, agglomeration, sintering, Ostwald ripening)
b. Modelling of population balance (MPB) (basics of der MPB, kernels of relevant processes für particles synthesis, solution of von MPB)
c. Gasphase processes for particles synthesis (relevant topics, flame processes, plasma processes, Hot wall reactors)
d. Liquid phase processes for particles synthesis (relevant topics, precipitation, crystallization, influence of crystal form)

5 Learning outcomes:

a. The students know the elementar processes of particles synthesis and work with the relevant literature. They are able to transfer the knowledge on different processes and they can analyse and understand the oberserved phenomena.
b. The students know and handle the basic methods of modelling of population balance and the can applicate this method for particles synthesis, reasonably
c. The students know and understand the most important processes of particles synthesis. They can analysis these processes. In particular, the students can analyse the product properties in dependence of processes parameters and they can optimize the synthesis process.

6 Degree-relevant examination(s):

[x] Final module examination (MAP) [] Module examination (MP) [] Partial module examination (MTP)

	Type	Duration or length	Weighting of grade for module grade
a), b)	Oral examination	30 Min.	100%

The teacher announces the type of examination within the first three weeks.

<table>
<tr><td>7</td><td>Required coursework (SL)/qualifizierte Teilnahme (QT):
<table>
<tr><th></th><th>Type</th><th>Duration or length</th><th>SL / QT</th></tr>
<tr><td>c)</td><td>Seminar-talk to an exemplary topic / process in the field of particles synthesis.</td><td>30 Min.</td><td>SL</td></tr>
</table>
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Course achievement (according to Nr. 7)</td></tr>
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<tr><td>11</td><td>This module is also an element of the following degree programmes:</td></tr>
<tr><td>12</td><td>Module coordinator:
Schmid</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
</table>

Ion Beam Analysis of Materials

Ion Beam Analysis of Materials

modul number:	Workload (h):	Credits:	Semester:	Frequency:	Duration (in Sem):
27	180	6	3.	WT	1

1 Module structure:

	Course	tyoe	Attendance(h)	Individual study time(h)	status (m/e)	group size
a	Ion Beam Analysis of Materials	L	15	30	e	
b	Ion Beam Analysis of Materials	P	30	60	e	up to 5
c	Ion Beam Analysis of Materials	S	15	30	e	up to 30

2 Options within the module:

none

3 Participation requirements:

none

4 Content of module:

a. **Lecture:**

Fundamentals of ion-solid-interactions and its applications for material analysis and modification, especially:

- Ion sources, ion optics, acceleration principles
- Interaction of ionizing radiation with biologic organisms and radioprotection
- Solid thin film analysis with Rutherford Backscattering Spectroscopy (RBS)
- Trace element analysis with Nuclear Reaction Analysis (NRA)
- Element detection with particle induced X-rays (PIXE)
- Ion-solid interaction, ion ranges, defect formation
- Doping of semiconductors with ion implantation
- Application of ion accelerators in astro-, geo-, nuclear and medicine physics
- Nano patterning with ion beams

b. **Practical training**:

- Preparation and examination of samples in the context of projects dealing with topics of the lecture using the accelerators at RUBION.

c. **Seminar**

- Presentation of experimental results and the theoretical background

5 Learning outcomes:

The course is held in collaboration with the Ruhr-University Bochum and gives an introduction to the fundamentals of nuclear solid state physics and applications of accelerator physics.

a. Fundamental concepts of this special field.
b. Autonomous acting, experimenting, as well as identification and extraction of essential relationships out of experimental experience. The students gain experience in the beam time operation of a large scale research facility.
c. Experience in web based cooperation in inter-university teams. Every team has to write an

<table>
<tr><td></td><td>analysis and documentation of results and to give an oral presentation of the outcomes.</td></tr>
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<table><tr><th></th><th>Type</th><th>Duration or length</th><th>weighting of grade for modul grade</th></tr><tr><td>b
c</td><td>Written project report with
presentation</td><td>ca. 30 pages
ca. 30 min.</td><td>100 %</td></tr><tr><td></td><td></td><td></td><td></td></tr></table>The teacher announces the type of coursework (or qualifizierte Teilnahme) within the first three weeks.</td></tr>
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none</td></tr>
<tr><td>9</td><td>Requirement for obtaining credits:
Passing of final module examination</td></tr>
<tr><td>10</td><td>Weighting of module grade in calculation of final overall grade:
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<tr><td>11</td><td>This module is also an element of the following degree programmes:
Physics M. Sc.</td></tr>
<tr><td>12</td><td>Module coordinator:
Lindner</td></tr>
<tr><td>13</td><td>Additional information:
Language english</td></tr>
<tr><td>14</td><td>Recommended literature:
M. Nastasi, J. W. Mayer, Y. Wang; Ion Beam Analysis: Fundamentals and Applications; CRC Press</td></tr>
</table>