Hochschule
Bonn-Rhein-Sieg
University of Applied Sciences

# Module Handbook
# „Materials Science and Sustainability Methods“
# Master of Science (M.Sc.)

## Department of Natural Sciences
## University of Applied Sciences Bonn-Rhein-Sieg

## Version 1
## 05.10.2022

**Change Notice:** **Cluster- Accreditation**

**Compulsory Courses:**



**Selected elective courses**

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| Module: | **Sustainable Materials 1 (Funktionalisierte Werkstoffe)** |
| Semester: | 1st semester |
| Course leader: | Prof. Dr. Peter Kaul |
| Lecturer: | Prof. Dr. Peter Kaul, Prof. Dr. Michael Bäcker, Prof. Dr. Johannes Steinhaus |
| Language: | German |
| Assignment to curriculum: | Compulsory course in 1st Sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 15 / 15<br>Practical course: 15 / 15<br><br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of mathematics, physics and materials science. |
| Learning outcomes: | The students are able to<br>• explain the (micro-) structure and the physical-technological functionality of functionalized materials,<br>• explain application examples of functionalized materials in the fields of Energy and Environmental Engineering, sensor technology, superconductivity and medical technology,<br>• explain the particular features, areas of application, specific advantages and disadvantages as well as manufacturing processes<br>my means of<br>• knowing the basic principles of solid-state physics,<br>• knowing the basics of functionlized semiconductors,<br>• knowing the properties of the main coatingsystems, matrices, as well as fiber- and fillersystems<br>• know the properties of functionalized semiconductor materials in different application areas<br>in order to<br>• define, design and apply the material- and functionalization concepts to the respective applications in a proper way<br>• predict and evaluate the properties of composite materials. |
| Summary indicative content: | Lecture:<br>Structure, technical functionality, properties, manufacturing processes, testing methods and areas of application of functionalized polymeric, metallic, ceramic and composite materials with a focus on:<br>• solid-state physics |

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| | • materials für sustainable Energy and Environmental Engineering<br>• materials for sensor- and actuatortechnologies<br>• biomedical materials<br>• interactions between funtionalized materials and different ambient media |
| Assessment: | Written examination (90 minutes) or oral exam (30 minutes) – graded |
| Teaching style: | V: PP, Overhead, blackboard<br>Ü/P: PP, Overhead, blackboard, programming with LabView, measuring techniques |
| Indicative bibliography/Sources: | • Göpel/Ziegler: Struktur der Materie: Grundlagen, Mikroskopie und Spektroskopie, B.G. Teubner Verlagsgesellschaft, Stuttgart – Leipzig; 1994<br>• William D. Callister und David G. Rethwisch: Materialwissenschaften und Werkstofftechnik, Wiley-VCH, Weinheim, 2013, ISBN: 978-3-527-33007-2<br>• Volkmar Stenzel und Nadine Rehfeld: Funktionelle Beschichtungen, Vincentz Network, Hannover, 2013, ISBN 3-86630-876-3, ISBN 978-3-86630-876-3<br>• Hansgeorg Hofmann und Jürgen Spindler: Verfahren in der Beschichtungs- und Oberflächentechnik, Fachbuchverlag Leipzig im Carl Hanser Verlag, München, Wien, 2010, ISBN: 978-3-446-42378-7<br>• Elvira Möller: Handbuch Konstruktionswerkstoffe: Auswahl, Eigenschaften, Anwendung, Carl Hanser Verlag, München, 2008, ISBN 978-3-446-40170-9<br>• Erich Winthermantel und Suk-Woo Ha: Medizintechnik: Life Science Engineering, Springer-Verlag, Berlin Heidelberg, 2009, e-ISBN 978-3-540-93936-8 |

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| Module: | **Materials Processing 1 (Conventional Processing Techniques)** |
| Semester: | 1st semester |
| Course leader: | Prof. Dr.-Ing. Christian Dresbach |
| Lecturer: | Prof. Dr.-Ing. Christian Dresbach, Prof. Dr. Johannes Steinhaus |
| Language: | English |
| Assignment to curriculum: | Compulsory course in 1st Sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 15 / 15<br>Practical course: 15 / 15<br><br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of mathematics, physics and materials science. |
| Learning outcomes: | The students are able to<br>• explain the basic materials processing techniques,<br>• describe the processing related material deformation mechanisms and transformations on the macro- and micro-scale,<br>• describe the process chain from different raw materials to a semi-finished part or finished product,<br>• evaluate sustainability aspects of raw material production and recycling potential<br>by means of<br>• comparing the different material processing paths,<br>• correlating the process-property relations,<br>• investigating micro-structural and mechanical properties<br>in order to<br>• decide which technique is appropriate for which application,<br>• identify the processing history of a component,<br>• investigate and evaluate component defects in relation to material processing failures. |
| Summary indicative content: | Thermoplastic Polymers:<br>• Types and properties of thermoplastic polymers<br>• Melting and mixing of polymers<br>• Master forming and forming processes<br>• Fiber production and processing<br>• Machining processes<br>• Welding and bonding techniques<br>• Sustainability aspects of polymer production |

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| | Metals and ceramics:<br>• Primary metal processing techniques, esp. deformation and casting methods<br>• Secondary metal processing techniques, esp. machining and heat treatments<br>• Sustainability aspects of metal production<br>• Influence of different metal processing steps on resulting microstructure and mechanical properties<br>• Processing steps of technical ceramics and their influence on resulting microstructure and mechanical properties<br>• Introduction to computer-based process selection considering sustainable aspects |
| Assessment: | Written examination (120 minutes) or oral presentation (30 minutes) – graded |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, student presentations<br>Practical course: demonstration lab courses, excursions |
| Indicative bibliography/Sources: | • Fritsche, Cornelia - Fachkunde Kunststofftechnik - 4., verb. Aufl., Haan-Gruiten: Verl. Europa-Lehrmittel, 2014.<br>• Oswald, Tim. Polymer Processing, Carl Hanser Verlag, 2006.<br>• Rauwendaal, Chris - Understanding Extrusion, 2nd Ed., Carl Hanser Verlag, 2010.<br>• Lumley, Fundamentals of aluminium metallurgy, WP 2011<br>• Ashby & Jones, Engineering Materials 2, Butterworth Heinemann, 1999<br>• Campbell, Complete casting handbook, 2nd Edition, Elsevier 2015<br>• Barsoum, Fundamentals of Ceramics, IOP Publishing Ltd 2003<br>• Salmang & Scholze, Keramik, 7. Auflage, Springer, 2007<br>• Ansys Granta EduPack software, ANSYS, Inc., (www.ansys.com/materials)<br>• Ashby, Material Selection in Mechanical Design, Elsevier 2005 |

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| Module: | **Materials Analysis 1 (Solid State Analytics)** |
| Semester: | $1^{st}$ semester |
| Course leader: | Prof. Dr. Marc Williams |
| Lecturer: | Prof. Dr. Marc Williams |
| Language: | English |
| Assignment to curriculum: | Compulsory course in $1^{st}$ Sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 60<br>Exercise: 15 / 30<br>Practical course: 15 / 15<br><br>Total: 75 / 105<br>**Total (contact hours + private study): 180 hours** |
| Credits: | 6 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Typical basic knowledge of physics, chemistry and analytical methods from bachelor courses |
| Learning outcomes: | The students are able to<br>• independently develop an analytical strategy for different solids and their characterising properties and conduct the corresponding measurements,<br>• developing criteria to evaluate measurement data obtained for example from literature<br>by means of<br>• understanding both the theoretical background as well as the practical execution of important solid-state analytical methods in the lecture,<br>• developing an analysis strategy for a problem at hand in a team, apply measurement techniques and assess the data and learn to identify typical error sources<br>in order to<br>• function as expert for materials, their properties and analysis methods,<br>• work in interdisciplinary teams, discuss results and present them in a professional manner. |
| Summary indicative content: | Lecture:<br>• characterising properties of materials and surfaces<br>• operation principles of measurement techniques for a variety of solid-state properties such as chemical composition, crystal structure, surface & bulk properties and particle size<br>• preparation and processing of solid samples and typical handling errors<br>• examples of in-situ measurement techniques, especially in |

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| | Production processes and catalysis<br>Exercise:<br>• exercises for calculation and evaluation of measurement techniques studied in the lecture<br>• evaluation and critical assessment of measurements found in scientific literature<br>Practical course:<br>• developing an analysis strategy for a fictional analysis assignment in a team with a presentation of the results in English<br>• Identification and characterization of technical materials with the techniques learned in the lecture |
| Assessment: | Final examination in written (120 minutes) or oral (30 minutes) form - graded |
| Teaching style: | Lecture: slides, whiteboard, online content<br>Exercise: compilation of exercises, whiteboard, slides, papers<br>Laboratory course: written instructions, original papers, application reports |
| Indicative bibliography/Sources: | • Skoog, Holler, Crouch: Principles of Instrumental Analysis (2017)<br>• Organic Chemistry, Brooks/Cole Pub Co, 2006 (O)<br>• Hermann: Crystallography and Surface Structure – (2016)<br>• Pecharsky, P.Y. Zavalij: Fundamentals of Powder Diffraction and Structural Characterization of Materials, Springer, 2009 (https://doi.org/10.1007/978-0-387-09579-0)<br>• Massa, Kristallstrukturbestimmung, Springer, 2015 (https://doi.org/10.1007/978-3-658-09412-6)<br>• Niemantsverdriet: Spectroscopy in Catalysis (2007)<br>• Selected papers from scientific literature |

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| Module: | **Schlüsselqualifikationen** |
| Semester: | $1^{st}$ semester |
| Course leader: | Dipl.-Ing. Dipl.-Wirt.-Ing. Tatjana Radowitz |
| Lecturer: | Dipl.-Ing. Dipl.-Wirt.-Ing. Tatjana Radowitz |
| Language: | German |
| Assignment to curriculum: | Compulsory course in 1st Sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 2 SWS<br>Practical course: 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 30 / 30<br>Practical course: 0 / 0<br><br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Good level of proficiency in German language |
| Learning outcomes: | The students are able to<br>• apply the basics of solution-oriented communication,<br>• lead and motivate oneself and others better,<br>• organize their workload efficiently and plan their time reasonable,<br>• set goals and achieve them,<br>• give and take feedback,<br>• analyse target groups and communicate, present, moderate, and transfer knowledge appropriate,<br>• prepare and conduct appraisal interviews<br>by means of<br>• apply methods to establish rapport to singles and groups,<br>• knowing their own behavior preference and recognize behavior preferences of counterparts,<br>• clarify work orders,<br>• decide situational, which strategy leads to the desired results<br>in order to<br>• act aim-oriented,<br>• solve interpersonal problems easier,<br>• solve assignments more effectively and efficiently. |
| Summary indicative content: | • basics of solution-oriented communication<br>• active listening, establish rapport<br>• paraphrasing and verbalise<br>• give and take feedback<br>• time-management<br>• achieving aims, SMART+<br>• personality and communication |

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| | • team and teambuilding<br>• methods of successful presentations 1<br>• analysing target groups, express the central message<br>• storytelling<br>• methods of successful presentations 2<br>• body posture, gesture, facial expression, voice, state-management<br>• creativity methods<br>• moderation skills<br>• Leadership - evaluate levels of maturity and apply appropriate management tools, plan and conduct appraisal interviews |
| Assessment: | Students have to write „knowlegde-storage-reports“ during term, which will be graded. |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, flip-chart, student presentations,<br>single and group exercises, role-play |
| Indicative bibliography/Sources: | • Hettl, Matthias K., Richtig führen ist einfach. Der Führungskompass zur wirksamen Mitarbeiterführung Taschenbuch – 2008<br>• Schulz von Thun, Friedemann, Miteinander reden, 1 Störungen und Klärungen, 2 Stile, Werte und Persönlichkeitsentwicklung, 3 Das innere Team und situationsgerechte Kommunikation Taschenbuch – 2008<br>• Corssen, Jens, Der Selbst-Entwickler: Das Corssen Seminar, Verlag: marix Verlag ein Imprint von Verlagshaus Römerweg – 2008<br>• Seiwert, Lothar, Das 1x1 der Persönlichkeit: Mehr Menschenkenntnis und Erfolg mit dem persolog®-Modell (GU Einzeltitel Lebenshilfe) Taschenbuch – 6. August 2016<br>• Spies, Stefan, Der Gedanke lenkt den Körper: Körpersprache - Erfolgsstrategien eines Regisseurs, Verlag: HOFFMANN UND CAMPE VERLAG GmbH – 2010<br>• Atkinson, Cliff, Erzählen statt aufzählen: Neue Wege zur erfolgreichen PowerPoint-Präsentation; 2. Auflage. Gebundene Ausgabe – 2009<br>• von Kanitz, Anja, Crashkurs Professionell Moderieren - inkl. Arbeitshilfen online, 1. Auflage 2015<br>• Brinkmann Manuela (Hrsg.) (Autor), Tatjana Radowitz (Autor), Susanne Schulze (Autor), et.al., „Konfliktkost leicht verdaulich“ – Feedback geben im Business mit NLP, Besser mit Business NLP. Praxisbeispiele für positive Veränderungen Verlag: Deutscher Verband für Neuro-Linguistisches Programmieren; Seite 75 – 98, Auflage: 1. Aufl. -2010 |

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| Module: | **Sustainable Materials 2 (Renewables)** |
| Semester: | 2nd semester |
| Course leader: | Prof. Dr. Margit Schulze |
| Lecturer: | Prof. Dr. Margit Schulze |
| Language: | English |
| Assignment to curriculum: | Compulsory course in 2nd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 2 SWS<br>Practical Course 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 30 / 30<br>Practical course: 0 / 0<br><br>Total: 75 / 105<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of organic and macromolecular chemistry |
| Learning outcomes: | The students are able to<br>• explain the most important technologies and methods to generate, isolate, purify and process renewable resources and to compare those processes with that one for fossil-resources,<br>• describe the synthesis and production of novel biobased materials including starting compounds and intermediates.,<br>• apply their knowledge and experience in order to design the entire process of renewable resource utilization for the development of biobased materials and their recycling potential,<br>• evaluate sustainability aspects of plant and crop cultivation/harvesting<br>by means of<br>• comparing the different biorefinery pathways,<br>• correlating the process-property relations,<br>• classifying chemical structures and related physico-chemical properties<br>in order to<br>• decide which biorefinery type is appropriate for what biomass,<br>• identify platform chemicals, intermediates, and final products,<br>• investigate and evaluate technological readiness level of the corresponding processes. |
| Summary indicative content: | Lecture/Exercises:<br>• For all contents: updates are required due to most recent developments |

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| | <ul><li>Sustainability concepts in chemical industry</li><li>Renewable resources used in chemical industry (status quo and future perspectives)</li><li>Availability, extraction, purification and processing of renewable resources</li><li>Biomass-based products: typical structure-property relationships or property profiles</li><li>Areas of application for materials from renewable resources</li><li>Strategies to re-use and/or re-cycle materials</li><li>Biorefinery concepts as an alternative to crude oil refineries</li><li>Chemical families of renewable materials, structures, properties, availability</li><li>Environmental and ethic aspects of biomass use</li><li>Basics of Cascade and Power-to-X concepts</li></ul> |
| Assessment: | Written examination (120 minutes), exercises and oral presentation (30 minutes) – graded |
| Teaching style: | Lecture/Exercise: beamer, videos, white/black board, student presentations, excursions |
| Indicative bibliography/Sources: | <ul><li>Kurt Wagemann and Nils Tippkötter, Biorefineries (2019) https://doi.org/10.1007/978-3-319-97119-3</li><li>Arno Behr and Thomas Seidensticker, Einführung in die Chemie nachwachsender Rohstoffe (2018) https://doi.org/10.1007/978-3-662-55255-1</li><li>Roadmap Chemie 2050 (2019) ISBN:978-3-89746-223-6. https://www.vci.de/vci/downloads-vci/publikation/2019-10-09-studie-roadmap-chemie-2050-treibhausgasneutralitaet.pdf</li><li>Scientific publications (available via LEA). Literature search is required for most recently published paper (via HBRS library access to Web of Science, SciFinder etc.)</li></ul> |

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| Module: | **Materials Processing 2 (Additive Manufacturing)** |
| Semester: | 2nd Semester |
| Course leader: | Prof. Dr. Johannes Steinhaus |
| Lecturer: | Prof. Dr. Johannes Steinhaus |
| Language: | English |
| Assignment to curriculum: | Compulsory course in 2. sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 15 / 15<br>Practical course: 15 / 15<br><br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of mathematics, physics and materials science. |
| Learning outcomes: | The students are able to<br>• explain the basic additive manufacturing techniques,<br>• describe the material transitions that are necessary to generate each layer appropriately,<br>• name the typical processing steps and required parameters settings (pre-processing, support structures, printing parameters and post-processing) for each additive manufacturing technique,<br>• know the different properties of materials for additive manufacturing and differences to materials used in conventional processing methods,<br>• evaluate sustainability aspects of additive manufacturing methods<br>by means of<br>• comparing the different additive material processing paths,<br>• correlating the process-property relations,<br>• investigating micro-structural and mechanical properties of additive manufactured parts<br>in order to<br>• decide which additive manufacturing technique is appropriate for which application,<br>• identify the additive processing history of a component,<br>• investigate and evaluate component defects in relation to material processing failures. |
| Summary indicative content: | • introduction to additive manufacturing processes<br>• basics additive manufacturing processing |

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| | • Stereolithography SLA<br>• Selective Laser Sintering SLS<br>• Fused Deposition Modelling FDM<br>• Laminated Object Manufacturing LOM<br>• Three-Dimensional Printing (3DP / TDP)<br>• Rapid Tooling<br>• additive manufacturing design rules<br>• data processing, 3D scanning and STL-data<br>• materials for additive manufacturing |
| Assessment: | Written examination (90 minutes) or oral Presentation (30 minutes) – graded |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, student presentations<br>Practical course: demonstration lab courses, excursions |
| Indicative bibliography/Sources: | • Andreas Gebhardt, Jan-Steffen Hötter. Additive Manufacturing, Hanser Publishers, 2016.<br>• Kaufui V. Wong and Aldo Hernandez. A Review of Additive Manufacturing. International Scholarly Research Network, ISRN Mechanical Engineering, Volume 2012, Article ID 208760,<br>• Andreas Gebhardt. Additive Fertigungsverfahren - Additive Manufacturing und 3D-Drucken für Prototyping - Tooling – Produktion. Carl Hanser Verlag GmbH & Company KG, 2017.<br>• Roland Lachmayer, Rene Bastian Lippert. Additive Manufacturing Quantifiziert - Visionäre Anwendungen und Stand der Technik, Springer Berlin Heidelberg, 2017. |

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| Module: | **Simulationsmethoden** |
| Semester: | $2^{nd}$ semester |
| Course leader: | Prof. Dr.-Ing. Christian Dresbach |
| Lecturer: | Prof. Dr.-Ing. Christian Dresbach |
| Language: | German |
| Assignment to curriculum: | Compulsory course in $2^{nd}$ sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 2 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 30 / 30<br>Exercise: 30 / 30<br>Practical course: 15 / 15<br><br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on bachelor level in structural analysis and mechanics of materials. |
| Learning outcomes: | The students are able to<br>• perform structural mechanics finite element simulations,<br>• identify reasonable materials for technical components<br>by means of<br>• simplifying complex component and loading situations,<br>• modelling component geometries with Ansys Workbench and APDL,<br>• searching reasonable materials using databases,<br>• defining necessary material properties,<br>• generating reasonable meshes and performing convergence studies,<br>• defining realistic boundary conditions,<br>• performing and evaluating finite element simulations<br>in order to<br>• dimension and assess mechanically loaded components,<br>• examine stress concentrations,<br>• recalculate material experiments,<br>• perform lifetime and reliability assessments. |

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| Summary indicative content: | • Introduction to finite element modeling<br>• Static mechanical FEM analyses with ANSYS Workbench and APDL<br>• Structural mechanic element types (bar, beam, plane, shell, volume)<br>• Non-linear FEM simulations (contact, plasticity, large deformations)<br>• Thermo-mechanical simulations<br>• Modal analysis and Euler buckling<br>• Explicit dynamic<br>• Computer based material selection |
| Assessment: | Term paper – graded |
| Teaching style: | Beamer, whiteboard, script, guided and independent working through written exercises, independent modeling of the tasks for the term paper. |
| Indicative bibliography/Sources: | • Ansys Help, ANSYS Inc., (www.ansys.com)http://www.ansys.com/materials<br>• Dean, Introduction to Finite Element Method, University of Cambridge<br>• Öchsner & Merkel, One-Dimensional Finite Elements, Springer<br>• Lee, Finite Element Simulation with Ansys Workbench 19, SDC, 2019<br>• Ansys Granta EduPack software, ANSYS Inc., (www.ansys.com/materials) |

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| Module: | **Nachhaltigkeitskonzepte** |
| Semester: | 2nd semester |
| Course leader: | Prof. Dr. Klaus Lehmann |
| Lecturer: | Prof. Dr. Klaus Lehmann, Dr. Stefan Albrecht, Dr. Michael Held |
| Language: | German |
| Assignment to curriculum: | Compulsory course in 2nd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 5 SWS (Seminar)<br>Exercise: 0 SWS<br>Practical course: 0 SWS<br><br>The teaching unit consists of two parts: General concepts of sustainability (3 SWS, Lehmann) and introduction to holistic accounting (Albrecht, Held 2 SWS). |
| Student workload: | Contact hours / Private study<br>Seminar: 45+30 / 65+40<br>Exercise: 0 / 0<br>Practical course: 0 / 0<br><br>Total: 75 / 105<br>**Total (contact hours + private study): 180 hours** |
| Credits: | 6 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | None |
| Learning outcomes: | The students are able to<br>• explain and discuss the sustainability paradigm from many perspectives,<br>• can classify sustainability as a normative concept,<br>• can classify a process or product called sustainable in a weighing way<br>by means of<br>• knowing different accounting procedures and can classify their results,<br>• reflectively grasp the functioning of the concept of sustainability by means of various examples and different methodological approaches<br>in order to<br>• to be engage in current professional, entrepreneurial and societal debates on sustainability-related transformations in an appropriate, argumentative and reflective manner.,<br>• to be able to accompany the transformation processes as a citizen and material scientist independently, appropriately and reflectively. |
| Summary indicative content: | Concepts of sustainability:<br>• Historical, definitional, ethical and discourse-analytical classification of the concept of sustainability.<br>• SDGs and the German Sustainability Strategy<br>• Planetary Boundaries and Donut Economics |

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| | • Footprint Concepts: MIPS and Ecological Footprint<br>• Mass balancing<br>• Basics of climate change, relationship between knowledge and morals<br>• Discussion of selected student examples<br>• Invitation of external experts on Responsible Care, Sustainability and Career Planning, or CSR<br>Ganzheitliche Bilanzierung:<br>• Introduction to the background and function of GaBi<br>• Discussion of results and their results<br>• Simulation exercises with the educational software version GaBi from Sphera<br>• Discussion of current accounting challenges (electromobility, consideration of circular-economy-processes, consideration of renewable raw materials) |
| Assessment: | Oral exam (40 minutes in groupes of two students) – graded |
| Teaching style: | Seminar-style teaching, hybrid also possible: PPT presentation, videos, blackboard/whiteboard, student presentations, small group work, systematic exchange rounds, feedback exercises, simulation programmes, role plays, excursion |
| Indicative bibliography/Sources: | • Eyerer, Peter, Ganzheitliche Bilanzierung. Werkzeug zum Planen und Wirtschaften in Kreisläufen, Springer, Heidelberg, 1996 und aktuelle Fachveröffentlichungen aus dem Fraunhofer IBP.<br>• Bundesregierung, Deutsche Nachhaltigkeitsstrategie 2021, Berlin 2021.<br>• Global Policy Forum. Agenda 2030: Wo steht die Welt? 5 Jahre SDGs. Eine Zwischenbilanz, Bonn 2020.<br>• Ott, Konrad et al., Handbuch Umweltethik, ausgew. Art., Metzler, Stuttgart, 2016.<br>• Stibbe, Rosemarie, Globales Life-Cycle-Controlling. Footprinting in der Praxis, Springer, Wiesbaden, 2017.<br>• Grunwald, Armin, Kopfmüller, Jürgen, Nachhaltigkeit, 3. Aufl., Campus, 2021.<br>• Steffen, Will, Rockström, Johan et al., Planetary boundaries. Guiding human development on a changing planet, Science 347, 2015, 6223 and supl.<br>• VCI. Dechema. Future Camp, Roadmap 2050. Auf dem Weg zu einer treibhausgasneutralen chemischen Industrie in Deutschland, Wiesbaden 2019. |

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| Module: | **Sustainable Materials 3 (Composites and Hybrid Structures)** |
| Semester: | 3rd Semester |
| Course leader: | Prof. Dr. Johannes Steinhaus |
| Lecturer: | Prof. Dr.-Ing. Bernhard Möginger, Prof. Dr.-Ing. Christian Dresbach, Prof. Dr. Johannes Steinhaus |
| Language: | English |
| Assignment to curriculum: | Compulsory course in 3rd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS (2 excursions e.g. Schütz Composites, DLR) |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 15 / 15<br>Practical course: 15 / 15<br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of physics and materials science and processing. |
| Learning outcomes: | The students are able to<br>• name the basic matrix, fiber and filler systems as well as their manufacturing and processing techniques,<br>• describe, simulate and calculate material modulus, -strength and co-efficient of thermal expansion of composites and hybrid structures,<br>• apply composite and hybrid concepts on given development tasks,<br>• evaluate sustainability aspects of the application of composites and hybrid structures<br>by means of<br>• comparing and correlating the main properties of matrix, fiber and filler systems,<br>• performing Weibull analyses and fracture mechanics evaluations,<br>• applying their knowledge of material simulation and FEA on composites and hybrid structures<br>in order to<br>• properly define and develop composite and hybrid concepts on technical applications,<br>• predict and evaluate the properties of composites and hybrid structures. |
| Summary indicative content: | • Introduction, technical terms, definitions, application examples |

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| | • Fiber and filler materials<br>• Resin and matrix materials<br>• Bonding and interfacial adhesion<br>• Curing kinetics and determination of kinetics parameters<br>• Processing methods<br>• General properties of composites and hybrid structures<br>• Mechanical properties of continuous strand composite<br>• Mechanical properties of short-fiber and particle filled composites<br>• Modelling modulus of short-fiber composites<br>• Interfacial properties, failure mechanisms and -analysis<br>• Joining and bonding techniques of composites und hybrid structures<br>• Basic principles of ceramic matrix composites<br>• Stress intensity factor and fracture toughness<br>• Weakest link theory<br>• Manufacturing, characterization and modelling of ceramic matrix composites |
| Assessment: | Written examination (120 minutes) or oral Presentation (30 minutes) – graded |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, student presentations<br>Practical course: demonstration lab courses, excursions |
| Indicative bibliography/Sources: | • R. Janda, Kunststoffverbundsysteme, VCH Verlag<br>• J. Summerscales, Microstructural Characterisation of Fiber-Reinforced Composites Tuttle, Structural Analysis of Polymeric Composite Materials<br>• M. Neitzel, U. Breuer, Die Verarbeitungstechnik der Faser-Kunststoff-Verbunde, Hanser Verlag<br>• T.D. Papathanasiou, D.C. Guell, Flow Induced Alignment in Composite Materials<br>• Robert M. Jones, Mechanics of Composite Materials, Hemisphere Publishing Corporation<br>• N.G. McCrum, C.P. Buckley, C.B. Bucknall, Principles of Polymer Engineering, Chapter 6 (Reinforced Polymers)<br>• Lewis, Forensic Polymer Engineering – Why Polymer Products Fail in Service<br>• Talreja, Damage and Failure of Composite Materials<br>• G. Habenicht: Kleben – Grundlagen, Technologie, Anwendungen<br>• Springer Verlag, ISBN 3-450-62445-7<br>• A.V. Pocius: Adhesion and Adhesive Technology – an Introduction<br>Hanser Verlag, 3-446-17616-0<br>• DELO, Bond it – Reference book on bonding technology<br>• Gross & Selig, Bruchmechanik, Springer, 2011<br>• Munz & Fett, ceramics, Springer 2011<br>• Barsoum, Fundamentals of ceramics, Tailor & Francis Group 2003<br>• Cantor et al., Metal and Ceramic Matrix Composites, IOP Publishing Ltd 2004<br>• Krenkel, Ceramic Matrix Composites, Wiley, 2008 |

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| Module: | **Sustainable Materials 4 (Strukturmaterialien)** |
| Semester: | 3rd Semester |
| Course leader: | Prof. Dr. rer. nat. Steffen Witzleben |
| Lecturer: | Prof. Dr. Christina Oligschleger, Prof. Dr. Steffen Witzleben, Dr. Moritz von Witzleben |
| Language: | German |
| Assignment to curriculum: | Compulsory Course 3rd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 25<br>Exercise: 35 / 25<br>Practical course: 15 / 5<br><br>Total: 95 / 55<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge from BSc. Courses in Mathematics, Physics, Chemistry and material sciences |
| Learning outcomes: | The students will be able to<br>• discuss, describe the chemistry, composition, properties and applications of ceramics, glasses, silicate binders and materials (cements, water glasses, and clay),<br>• discuss, describe the Composite materials of these material classes and the possibilities of developing special property profiles,<br>• describe in-depth knowledge of modern methods of production, formulation and application of these materials and the ability to transfer this knowledge to practice,<br>• define the use of sustainable manufacturing processes for these materials and their limits,<br>• The students apply the acquired practical and methodological skills in order to be able to plan the use of materials<br>by means of<br>• being able to independently reproduce important structure-property relationships of important ceramic, amorphous and silicate materials,<br>• interpret the evaluation of the various analyzes with regard to the structures,<br>• knowing the influence of production on the properties of the materials,<br>• researching the relevant original literature on a specific question<br>in order to<br>• interpreting the properties of silicate materials and to recognize, describe and predict important material |

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| | transformations,<br>• developing solutions for the development of new silicate materials independently,<br>• assigning structure-property relationships. |
| Summary indicative content: | Lectures:<br>The course based on the basics of general and inorganic chemistry, as typically taught in a relevant bachelor's degree.<br>1) Glass technology Silicate glasses, non-crystalline Substances - ''New glasses'', structure elucidation, theory and experiment, modeling of amorphous substances, oxide glasses, chalcogenide and halide glasses, metallic glasses, laser and optoelectronic properties, mechanical properties<br>2) Ceramics, technology, structures, properties, sustainability<br>3) Silicate building materials, cement chemistry and construction chemistry, determination and assessment of the sustainability of these materials<br><br>Practical part:<br>Production of selected silicate materials<br>• Testing of silicate materials according to relevant standards<br>• Demonstration trials<br>• Excursions<br>• Simulation experiments |
| Assessment: | Written examination (120 min) – graded |
| Teaching style: | PowerPoint, Whiteboard, Script, Video |
| Indicative bibliography/Sources: | • Scholze, H.: Glas Vogel, W.: Glaschemie Kühne,<br>• R.W. Cahn, P. Haasen, E.J. Kramer (eds.) Materials Science and Technology, Vol. 9 and Vol. 11<br>• Taylor: Cement Chemistry<br>• Scholz, Hierse, Möring, Baustoffkenntnis, Werner-Verlag |

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| Module: | **Materials Analysis 2 (Polymer Analytics)** |
| Semester: | 3rd semester |
| Course leader: | Prof. Dr. Johannes Steinhaus |
| Lecturer: | Prof. Dr. Johannes Steinhaus |
| Language: | English |
| Assignment to curriculum: | Compulsory course in 3rd Sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 60<br>Exercise: 15 / 30<br>Practical course: 15 / 15<br><br>Total: 75 / 105<br>**Total (contact hours + private study): 180 hours** |
| Credits: | 6 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Typical basic knowledge of physics, polymer chemistry, materials science and analytical methods from bachelor courses. |
| Learning outcomes: | The students are able to<br>• explain the main polymer analytics and testing methods,<br>• explain the polymer processing history on micro-structural, thermal and mechanical properties,<br>• decide which method suits for the fields of process monitoring, quality insurance, benchmarking and failure analysis,<br>• evaluate a polymer failure analysis from the literature with respect to quality, reasonability and improvability<br>by means of<br>• comparing the different polymer analytics and testing methods,<br>• correlating their significance for an analytical task,<br>• investigating micro-structural, thermal and mechanical properties of failed polymer parts and comparing them with OK parts<br>in order to<br>• decide which analytical technique is appropriate for which analytical task,<br>• identify the polymer processing history of a component,<br>• investigate and evaluate polymer component defects in relation to material processing failures,<br>• conduct a polymer failure analysis on their own. |
| Summary indicative content: | • Kinds of polymers<br>• Influence of polymer processing on material- and ageing-properties |

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| | • Mechanical testing<br>• Thermal analysis methods<br>• Microscopy methods<br>• Spectroscopy and chromatography methods<br>• Computer tomography methods<br>• Stability and ageing testing<br>• Suitability of polymer analytical methods for failure analysis |
| Assessment: | Written examination (90 minutes) or oral (30 minutes) Presentation – graded |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, student presentations<br>Practical course: demonstration lab courses, excursions |
| Indicative bibliography/Sources: | • T.A. Osswald, G. Menges (2012): Materials Science of Polymers for Engineers, 3rd Edition, Carl Hanser Verlag (Munich)<br>• G.W. Ehrenstein, G. Riedel, P. Trawiel (2004): Thermal Analysis of Plastics – Theory and Practice, Carl Hanser Verlag (Munich)<br>• T.R. Crompton (2013): Thermal Methods of Polymer Analysis, Smithers Rapra Technology Ltd (Shawbury)<br>• P.R. Lewis, C. Gagg (2010): Forensic polymer engineering, CRC Press (Boca Raton)<br>• W. Grellmann, S. Seidler: Kunststoffprüfung, 3. aktualisierte Auflage (2015), Carl Hanser Verlag (München)<br>• G.W. Ehrenstein, G. Riedel, P. Trawiel: Thermische Analyse von Kunststoffen, Carl Hanser Verlag (München)<br>• G.W. Ehrenstein: Kunststoff-Schadensanalyse - Methoden und Verfahren, 1. Aufl. (1992), Carl Hanser Verlag, München<br>• Lewis, Forensic Polymer Engineering – Why Polymer Products Fail in Service |

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| Module: | **Integrierte Managementsysteme** |
| Semester: | 3rd Semester |
| Course leader: | Prof. Dr.-Ing. Paul Melcher |
| Lecturer: | Prof. Dr.-Ing. Paul Melcher and/or MSc. Julian Steiger |
| Language: | German |
| Assignment to curriculum: | Compulsory course in 3rd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Exercise: 2 SWS<br>Practical Course 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 30 / 30<br>Practical Course 0 / 0<br><br>Total: 75 / 75<br>**Total (contact hours + private study): 150 hours** |
| Credits: | 5 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of Quality control |
| Learning outcomes: | According to BLOOM's (1956) taxonomy of learning levels, as revised by ANDERSON and KRATHWOHL (2001), students have the following competencies at the six learning levels (remember-understand-apply-analyse-evaluate-create).<br><br>The students are able to<br>• explain basic management models,<br>• understand all requirements of international standards on quality management systems (DIN EN ISO 9001), environmental management systems (DIN EN ISO 14001), energy management systems (DIN EN ISO 50001) and management-systems for safety and health at work (DIN ISO 45001) and explain them through oral presentations.<br>• understand the differences between management manuals, processes, procedures and work instructions,<br>• recognise and analyse sustainability aspects in integrated management systems<br>by means of<br>• analysing the conformity to standards in Integrated Management Systems with the associated processes, procedures and instructions,<br>• apply the eight basic tools of quality management and methods such as 8D report, 5 Why and FMEA,<br>• estimate and calculate quality and process costs,<br>• create audit questions related to the standard requirements with the acquired knowledge, |

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| | • analyse current issues related to the 17 sustainability goals in the exercises using internet research, comparing environmental and energy aspects<br>in order to<br>• analyse the results and interactions between management systems,<br>• decide how to create or change integrated management systems with their process map with management, implementation and support processes,<br>• to improve sustainability goals and aspects in integrated management systems,<br>• to be able to contribute to EU sustainability reports. |
| Summary indicative content: | • Basic issues of sustainability and management models<br>• Auditing of management systems according to DIN EN ISO 19011:2018<br>• Quality (terms and basics)<br>• Integrated management systems<br>• Quality management according to DIN EN ISO 9001:2015<br>• Processes, procedures, instructions<br>• Environmental management according to DIN EN ISO 14001: 2015<br>• Tools and methods<br>• Energy management according to DIN EN ISO 50001:2018<br>• Quality costs and process costs<br>• Safety and health at work according to DIN ISO 45001:2018<br>• Sustainability goals and aspects in integrated management systems |
| Assessment: | Module examination - graded portfolio examination<br>Consisting of:<br>25% Oral presentation (5 minutes) of at least one term paper with examination questions.<br>75% Written final examination (120 minutes) |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, student presentations,<br>logging of results of exercises in group work on the learning platform LEA to a wiki. |

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| Indicative bibliography/Sources: | Primary literature relevant to the exam:<br>• DIN EN ISO 9000<br>• DIN EN ISO 9001<br>• DIN EN ISO 14001<br>• DIN ISO 45001<br>• DIN EN ISO 50001<br>• DIN EN ISO 19011<br><br>Literature supplement (recommendation for Master's thesis or professional practice)<br>• Binner, Hartmut, F. : "Holistic Business Model Transformation-Systematic process digitalisation with the MITO method tool" Springer Vieweg Verlag, September 2020, 252 pages, ISBN 978-3-658-30232-0, Hardcover & eBook<br>• BPM CBOK® - Business Process Management BPM Common Body of Knowledge, Version 3.0, Guide to Process Management by European Association of Business Process Management EABPM (ed.)<br><br>Trade journals (recommendation for master thesis or profession)<br>• https://www.qz-online.de/<br>• https://www.zfo.de/<br>• https://www.projektmagazin.de/<br>• https://www.vdi-nachrichten.com/<br><br>Learning videos relevant to exams on the eight basic QM tools<br>• YouTube: Melcher, DGQ<br><br>Current secondary and special articles are uploaded to the learning units on LEA |
| Other: | There are learning control questions for each teaching unit for your own learning control. |

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| Module: | **Masterprojekte 1, 2 und 3** |
| Semester: | 1st semester, 2nd semester and 3rd semester |
| Course leader: | Prof. Dr. Johannes Steinhaus |
| Lecturer: | all lecturers |
| Language: | German or English |
| Assignment to curriculum: | Compulsory course in 1st, 2nd and 3rd sem. MSc. Materials Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of hands-on projects:<br>Lecture: 0 SWS<br>Exercise: 0 SWS<br>Practical Course: 2 SWS |
| Student workload: | Contact hours / Private study / independent practical work<br>Lecture 0 / 0<br>Exercise: 0 / 0<br>Practical course: 30 / 150<br><br>Total: 30 / 150<br>**Total (contact hours + private study): 180 hours** |
| Credits: | 6 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on bachelor level in the fields of scientific work and statistics as well as practical working skills in laboratories and pilot plant surroundings. |
| Learning outcomes: | The students are able to<br>• define and work on a complex, practical scientific problem within a limited time frame and to assess and communicate the results<br>by means of<br>• selecting, applying and proving suitable procedures, strategies and methods learned during their studies,<br>• evaluating and scrutinizing the results they obtained by using their acquired knowledge,<br>• define suitable criteria for the technical assessment and by means of sustainability and use these criteria to assess the results obtained,<br>• preparing, presenting and communicating the project results in a suitable way<br>in order to<br>• answer actual research questions in the fields of technology, science, society and sustainability on a project base. |
| Summary indicative content: | Within a master project, an actual problem related to materials science from the field materials development, material testing/-analytics, product development, process optimization or sustainability assessments should be answered.<br>The students might work in a laboratory/ technical centre in order to work on the research questions or might perform simulations, |

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| | modeling or literature research in order to assess and solve the scientific problem.<br>The projects can be performed as group work with up to 3 students or as individual work.<br>Scope and extent of the documentation depends on the question to be worked on and must be agreed with the respective lecturer. |
| Assessment: | Report (approximately 20 pages) and oral presentation (10 minutes) – not graded |
| Teaching style: | PowerPoint, Overhead, white bord |
| Indicative bibliography/Sources: | Bibliography is defined by the research question. |

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| Module: | **Final Thesis** |
| Semester: | $4^{th}$ semester |
| Course leader: | Course leaders of the department |
| Lecturer: | Course leaders of the department |
| Language: | German or English |
| Assignment to curriculum: | Compulsory course in $4^{th}$ sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The Master thesis is done either in research groups of the Bonn-Rhein-Sige University of applied Science or in national or international research groups, which offer research activities which match the focus of the study program.<br>During the master thesis, the students are supervised by at least one professor from the department, who also evaluates the final thesis. Details can be found in the examination regulations. |
| Student workload: | Contact hours: 17,5 weeks, with a work load of 40 hours/week<br>Private study (writing of thesis, preparing of oral presentation, learning for final exam): 5 weeks, with a work load of 40 hours/week<br>**Total Sum: 900 hours** |
| Credits: | 30 ECTS |
| Prerequisites according to Examination Regulations: | Admission to Master thesis, if not more than two compulsory courses have not been passed.<br>Admission to the Master thesis is regulated in the Examination Regulations. |
| Recommendations: | Basic knowledge on bachelor level in the fields of scientific work and statistics as well as practical working skills in laboratories and pilot plant surroundings. |
| Learning outcomes: | The students are able to solve independently and in a given time complex scientific questions in their special fields of work. They are also able to present their results both literally and orally in German and English in an adequate manner.<br>The Master thesis demonstrates the ability for independent scientific work, and the competence to use theoretical and analytical abilities for the solution of specific scientific questions. It also reveals social competence as well as the ability to solve complex problems. |
| Summary indicative content: | Theoretical and practical work to solve research-related questions using scientific methods. Practical application of knowledge and skills gained during the Master studies, and their accentuation in specific topics. The results have to be summarized in a scientific document, i.e. the Master thesis. The students present their results in a defined time frame, and defend their results in a final oral examination. |
| Assessment: | Master-Thesis: graded and oral examination (45 minutes): graded |

## Selected elective courses

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| Module: | **Werkstoffe der Luft- und Raumfahrt** |
| Semester: | 1st or 3rd semester |
| Course leader: | Prof. Dr.-Ing. Christian Dresbach |
| Lecturer: | Prof. Dr.-Ing. Christian Dresbach, Dr. Eric Breitbarth, Dr. Jan Haubrich |
| Language: | German |
| Assignment to curriculum: | Elective course in 1st or 3rd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 2 SWS<br>Exercise: 1 SWS<br>Practical Course: 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 30 / 30<br>Exercise: 15 / 15<br>Practical Course 0 / 0<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on bachelor level in material science and mechanics of materials. |
| Learning outcomes: | The students are able to<br>• comparatively evaluate materials for aerospace applications by considering aspects of sustainabilit,<br>• explain the relations between microstructure and mechanical properties,<br>• identify relevant material demands in aerospace components,<br>• calculate elastic anisotropic material behaviour and properties of composites<br>by means of<br>• analysing typical loading situations in airplanes,<br>• comparing material properties in the context of application,<br>• evaluating phase and transformation diagrams,<br>• calculating Hooke's law in matrix and tensor formulation,<br>• using rules of mixture<br>in order to<br>• identify and modify appropriate materials for sustainable aerospace applications,<br>• design application specific composite materials,<br>• perform lifetime and reliability assessments. |
| Summary indicative content: | • Importance of materials in aerospace applications<br>• Loading situations in airplane fuselages and engines<br>• Overview of materials in aerospace applications<br>• Elasticity (1D, 2D, 3D), anisotropy, effective elastic properties |

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| | • Modeling of metal plasticity<br>• Selected materials in detail, e.g.<br>  • nickel based superalloys<br>  • titanium alloys<br>  • titanium aluminides<br>  • hybrid material systems |
| Assessment: | Written examination (120 minutes) or oral presentation (20 minutes) – graded |
| Teaching style: | Beamer, whiteboard, exercises, student short presentations |
| Indicative bibliography/Sources: | • Mouritz, Introduction to Aerospace Materials, Woodhead Publishing, 2012<br>• Gudmundsson, General Aviation Aircraft Design, Elsevier, 2014<br>• Rolls Royce, The Jet Engine, Rolls-Royce plc, 1986<br>• Altenbach, Kontinuumsmechanik, Springer, 2012<br>• Rösler, Mechanisches Verhalten der Werkstoffe, Springer Vieweg, 2012<br>• Ashby, Materials Selection in Mechanical Design, Springer, 2006<br>• Bürgel, Maier, Niendorf, Handbuch Hochtemperatur Werkstofftechnik, Vieweg + Teubner, 2011<br>• Reed, The Superalloys, Cambride University Press, 2006<br>• Leyens & Peters, Titanium and Titanium Alloys, Wiley-VCH, 2003<br>• Lütjering & Williams, Titanium, Springer, 2007<br>• Appel et al., Gamma Titanium Aluminide Alloys, Wiley VCH, 2011 |

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| Module: | **Kunststoffrecycling und Maritime Müllproblematik** |
| Semester: | 3rd semester |
| Course leader: | Prof. Dr. Johannes Steinhaus |
| Lecturer: | Prof. Dr. Johannes Steinhaus |
| Language: | German (English; English literature is part of the course) |
| Assignment to curriculum: | Elective course in 3rd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 2 SWS<br>Seminar: 1 SWS<br>Practical Course: 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 30 / 30<br>Tutorial: 15 / 15<br>Practical Course: 0 / 0<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge of polymers and polymer processing |
| Learning outcomes: | The students are able to<br>• name the most commonly used plastic types in the fields of packaging, construction, agriculture, textile- and toy industry.,<br>• name and explain the commonly used analysis techniques for polymer and micro-plastics identification and characterization,<br>• realize ageing mechanisms of polymers,<br>• name the origin and main pathways of marine plastic litter and its impact on the habitats,<br>• name and describe the necessary processes and requirements on the recycling of sorted, mixed and contaminated plastic litter<br>by means of<br>• having a broad overview of the most commonly used plastic types in the fields of packaging, construction, agriculture, textile- and toy industry,<br>• knowing the functionality of the commonly used analysis techniques for polymer and micro-plastics identification and characterization,<br>• knowing typical processing and life-cycle dependent ageing mechanisms of polymers,<br>• evaluating the production and main pathways of marine plastic litter and its impact on the habitats,<br>• evaluating the necessary processes and requirements on the recycling of sorted, mixed and contaminated plastic litter<br>in order to<br>• understand how plastic litter pathways can be attributed to certain polymer applications,<br>• choose and apply commonly used analysis techniques for |

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| | polymer and micro-plastics identification and characterization,<br>• evaluate and control typical processing and life-cycle dependent ageing mechanisms of polymers,<br>• understand the production and main pathways of marine plastic litter and its impact on the habitats and develop effective counter-measures,<br>• understand and possibly optimize the processes and requirements on the recycling of sorted, mixed and contaminated plastic litter. |
| Summary indicative content: | • Introduction to polymer recycling and marine littering<br>• Identification and analysis of polymers/micro-plastics<br>• Ageing of polymers during production, processing, application and recycling<br>• Marine litter, micro- and nano-plastics<br>• Recycling of sorted plastic litter<br>• Recycling of mixed and contaminated plastic litter |
| Assessment: | Oral presentation (20 minutes) – graded |
| Teaching style: | Lecture: Power Point presentations (beamer, smartboard), blackboard/smartboard, videos<br>Seminar: presentations, flip-chart, teamwork |
| Indicative bibliography/Sources: | • D. Barcelo. Comprehensive Analytical Chemistry, Vol. 75 - Characterization and Analysis of Microplastics, Elsevier, 2017.<br>• Bergmann et al., Marine Anthropogenic Litter, Springer Open, 2015<br>• Kusch P. Application of Pyrolysis-Gas Chromatography/ Mass Spectrometry (Py-GC/MS). Comprehensive Analytical Chemistry, Vol. 75, Characterization and Analysis of Microplastics, Elsevier, 2017.<br>• Kusch P, Steinhaus J. Thermal Analysis of Polymers: Methods and Developments, Chapter: Thermal Analysis in Aerospace and Automotive Sectors. Ed. Pielichowski K, Wiley-VCH Verlag GmbH, 2022.<br>• Shim, Won Joon, Sang Hee Hong, and Soeun Eo. "Marine microplastics: abundance, distribution, and composition." Microplastic Contamination in Aquatic Environments. Elsevier, 2018.<br>• Fraunhofer UMSICHT: Kunststoffe in der Umwelt – Konsortialstudie Mikroplastik, 2018<br>• Boucher, J. und D. Friot. Primary microplastics in the oceans. A global evaluation of scources. Gland, Switzerland: IUCN International Union for the Conservation of Nature, 2017 |

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| Module: | **Einführung in die Molekulardynamik** |
| Semester: | 2nd Semester |
| Course leader: | Prof. Dr. Christina Oligschleger |
| Lecturer: | Prof. Dr. Christina Oligschleger |
| Language: | German |
| Assignment to curriculum: | Elective course in 2nd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 2 SWS<br>Exercise: 0 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 30 / 30<br>Exercise: 0 / 0<br>Practical course: 15 / 15<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge of differential and motion equations (corresponding to the BSc modules Mathematics and Physics) |
| Learning outcomes: | The students are able to<br>• assess the advantages and disadvantages of MD simulations,<br>• Set the test parameters depending on the desired design for the MD program,<br>• graphically display, analyze and interpret the results of the simulations,<br>by means of<br>• confidently understand the input and output of the existing MD code,<br>• specifically change the necessary files,<br>• master the evaluation programs<br>in order to<br>• investigate suitable problems related to fundamental atomic processes using the MD method,<br>• place and classify the results in a scientific context. |
| Summary indicative content: | Introduction to the problem, potentials, force fields, structure exploration, dynamics, thermodynamics, introduction to the Molecular Dynamics program, simulation of solids and their properties (vibrational states, relaxation, decomposition, fracture behavior), use of freeware programs to visualize the results |
| Assessment: | Graded<br>Elaboration of the MD project in the form of a scientific article |
| Teaching style: | Overhead, white board, power point |
| Indicative bibliography/Sources: | • Kutzelnigg, Einführung in die Theoretische Chemie (Bd. 1 und 2)<br>• Rapaport, The Art of Molecular Dynamics |

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| Module: | **Festkörperphysik und -eigenschaften** |
| Semester: | $1^{st}$ and $3^{rd}$ semester |
| Course leader: | Prof. Dr. Christina Oligschleger |
| Lecturer: | Prof. Dr. Christina Oligschleger |
| Language: | German |
| Assignment to curriculum: | Elective course in $1^{st}$ or $3^{rd}$ sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 2 SWS<br>Seminar: 1 SWS<br>Practical course: 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 30 / 30<br>Exercise: 15 / 15<br>Practical course: 0 / 0<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge of corresponding to the BSc modules Physics and solid state analytics |
| Learning outcomes: | The students are able to<br>• understand the main concepts of solid state physics,<br>• differ between crystalline, amorphous and liquid phase,<br>• work with harmonic approximations and with non-harmonic expansion,<br>• calculate properties of crystalline solids,<br>• distinguish static properties from dynamics and thermodynamics properties<br>by means of<br>• confidently understanding the differences between direct space and reciprocal space,<br>• applying the formulae in harmonic approximation,<br>• knowing the influences from structures and from dynamics<br>in order to<br>• interpret structural pattern,<br>• determine elastic properties from dispersion curves. |
| Summary indicative content: | Solids, crystals (international table of crystallography), scattering, direct space and reciprocal space, potentials/interactions, harmonic approximation, break down of harmonic approximation, potentials, properties (structural, dynamic, thermodynamic), electronic properties |
| Assessment: | Oral presentation (20 minutes): graded |
| Teaching style: | Overhead, white board, power point |
| Indicative bibliography/Sources: | • N.W. Ashcroft und N.D. Mermin: Solid State Physics, (Sounders College, Philadelphia, 1988)<br>• N.W. Ashcroft und N.D. Mermin: Festkörperphysik, (R. |

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| | Oldenbourg Verlag, München, 2001)<br>• K. Kopitzky: Einführung in die Festkörperphysik (Teubner, Stuttgart, 1993)<br>• H. Ibach und H. Lüth: Festkörperphysik, (Springer, Berlin, 2002)<br>• W. Raith: Bergmann Schaefer, Lehrbuch der Experimentalphysik — Festkörper, (Walter de Gruyter, Berlin, 1992)<br>• K.H. Hellwege: Einführung in die Festkörperphysik, (Springer, Berlin,1976)<br>• Charles Kittel: Einführung in die Festkörperphysik, (R. Oldenbourg Verlag, München, 2002)<br>• Christian Weissmantel und Claus Hamann: Grundlagen der Festkörperphysik, (Wiley-VCH Verlag, Weinheim, 1995) |

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| Module: | **Statistische Versuchsplanung** |
| Semester: | $2^{nd}$ Semester |
| Course leader: | Prof. Dr. Christina Oligschleger |
| Lecturer: | Prof. Dr. Christina Oligschleger |
| Language: | German |
| Assignment to curriculum: | Elective course in $2^{nd}$ sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 2 SWS<br>Exercise: 0 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 30 / 30<br>Exercise: 0 / 0<br>Practical course: 15 / 15<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | None |
| Learning outcomes: | The students are able to<br>• assess different test plans and carry out their evaluation,<br>• select and draw up suitable plans for specific problems,<br>• optimize problems<br>by means of<br>• knowing the differences between the different plans,<br>• understanding the statistical evaluation,<br>• Considering errors and determination of measurement errors<br>in order to<br>• find suitable settings for experiments in the case of concrete questions,<br>• optimize settings in operational processes. |
| Summary indicative content: | Lectures:<br>• Introduction to $2^k$ und $3^k$-plans<br>• Setting up sub-factor plans and the problem of mixing effects<br>• Evaluation of the test plans<br>• Determination of outliers in tests/check for normal distribution of the measurements<br>• Check for linearity and confidence intervals of the regression coefficients<br>• Optimization methods/Steepest Descent |
| Assessment: | graded module exam<br>elaboration of a project or submission of tasks |
| Teaching style: | V/P: (digital and analogue) blackboard, overhead projector, transparencies; Projector; textbooks; Computer; software development tools |

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| Indicative bibliography/Sources: | • Siebertz K, van Bebber D und Hochkirchen T, Statistische Versuchsplanung ISBN 978-3-642-05492-1, Springer, Berlin-Heidelberg (2010)<br>• Montgomery DC, Design and Analysis of Experiments. ISBN 978-0-470-45687-3, John Wiley & Sons, Inc. (2009)<br>• Scheffler E, Statistische Versuchsplanung und -auswertung, Deutscher Verlag für Grundstoffindustrie, Stuttgart (1997) |

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| Module: | **Betriebsfestigkeit und Bruchmechanik** |
| Semester: | 1st and 3rd semester |
| Course leader: | Prof. Dr.-Ing. Christian Dresbach |
| Lecturer: | Prof. Dr.-Ing. Christian Dresbach, Dr. Eric Breitbarth |
| Language: | German |
| Assignment to curriculum: | Elective course in 1st or 3rd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 1 SWS<br>Seminar: 1 SWS<br>Practical course: 1 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 15 / 15<br>Exercise: 15 / 15<br>Practical course: 15 / 15<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on bachelor level in material science and mechanics of materials |
| Learning outcomes: | The students are able to<br>• characterize static and dynamic material behaviour,<br>• dimension technical components against static and dynamic failure,<br>• describe crack propagation behaviour<br>by means of<br>• planning, conducting and evaluating static and dynamic material experiments,<br>• performing calculated proof of strength for machine components against static and cyclic loadings as well as calculated proof of operational strength,<br>• planning, conducting and evaluating fracture mechanical experiments,<br>• performing fracture mechanical component calculations<br>in order to<br>• identify suitable materials for secure technical applications,<br>• perform lifetime predictions and calculated failure evaluations for safety-relevant technical applications. |
| Summary indicative content: | • Dimensioning against static failure<br>• Experimental characterization of fatigue<br>• Proof of endurance strength<br>• Proof of operational strength<br>• Basics of linear elastic fracture mechanics<br>• Experimental characterization of fracture mechanical behaviour<br>• Stress corrosion cracking |

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| | • Cyclic crack propagation<br>• Fracture behaviour in superimposed loading |
| Assessment: | Written examination (120 minutes) or oral presentation (20 minutes) – graded |
| Teaching style: | Beamer, whiteboard, exercises, lab demonstrations |
| Indicative bibliography/Sources: | • Munz & Fett, Ceramics, Springer, 2001<br>• FKM, Rechnerischer Festigkeitsnachweis für Maschinenbauteile, VDMA Verlag, 2003<br>• Haibach, Betriebsfestigkeit, Springer, 2006<br>• Gross & Seelig, Bruchmechanik, Springer, 2011<br>• Richard & Sander, Ermüdungsrisse, Vieweg + Teubner, 2008<br>• Bürgel et al., Werkstoffmechanik, Springer-Vieweg, 2014<br>• Skolaut, Maschinenbau, Springer Vieweg, 2014 |

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| Module: | **Additive Fertigung keramischer Bauteile** |
| Semester: | 1st and 3rd semester |
| Course leader: | Dr. rer. nat. Dieter Nikolay |
| Lecturer: | Dr. rer. nat. Dieter Nikolay |
| Language: | German |
| Assignment to curriculum: | Elective course in 2nd sem. MSc. Material Science and Sustainability Methods |
| Course units/ Lesson hours per week (SWS): | The course consists of:<br>Lecture: 3 SWS<br>Seminar: 0 SWS<br>Practical course: 0 SWS |
| Student workload: | Contact hours / Private study<br>Lecture: 45 / 45<br>Exercise: 0 / 0<br>Practical course: 0 / 0<br><br>Total: 45 / 45<br>**Total (contact hours + private study): 90 hours** |
| Credits: | 3 ECTS |
| Prerequisites according to Examination Regulations: | None |
| Recommendations: | Basic knowledge on Bachelor level in the fields of ceramic's properties, manufacturing methods of plastics, metals and ceramics |
| Learning outcomes: | The students are able to<br>• name and describe the differences in the production of plastic components, metal components and ceramic components,<br>• name and describe the differences and similarities compared to conventional manufacturing processes<br>by means of<br>• explaining the basic workflow of 3d printing starting from cad data,<br>• naming and describing the different 3D printing processes according to the standard,<br>• naming the 3D printing processes according to the standard and differentiate them from each other,<br>• explaining the process chain of the different processes from raw material to the finished part,<br>• explaining construction and design aspects in reference to 3D printing<br>in order to<br>• decide which manufacturing process is suitable for which application. |
| Summary indicative content: | Lecture:<br>• Definitions of terms relating to 3D printing<br>• Classification of 3D printing processes into<br>  • Binding Processes<br>  • Deposition Processes |

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| | • Presentation, Explanation and Illustration of the 5 relevant 3d printing processes for metals + plastics<br>  • Vat Photopolymerisation (VPP)<br>  • Powderbed Fusion (PBF)<br>  • Binder Jetting (BJT)<br>  • Material Extrusion (MEX)<br>  • Material Jetting (MJT)<br>• Comparison of material and component properties<br>• Comparison of process times and costs<br>• Transfer of knowledge to the production of ceramics:<br>  • Focus on the differences to metal and plastic production<br>  • Presentation of different machines<br>  • Material properties<br>  • Research results<br>  • Development topics<br>• Design and BIONIK<br>• Comparison of additive manufacturing against subtractive manufacturing<br><br>Practical part:<br>• Creation of CAD designs for 2 different 3D printing processes<br>• Accompanying the manufacturing process in practice |
| Assessment: | Oral presentation (20 minutes): graded. |
| Teaching style: | Lecture/Exercise: beamer, videos, whiteboard, student presentations<br>Practical course: demonstration lab courses, excursions |
| Indicative bibliography/Sources: | • Kollenberg, W.: Additive Fertigung keramischer Komponenten: Grundlagen und Anwendung. Vulkan Verlag 2020<br>• Deckers, J.: Additive Manufacturing of Ceramics: A Review. J. Ceram. Sci. Tech., 05 [04] 245-260 (2014)<br>• Gibson, Ian et al: Additive Manufacturing Technologies; 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. Springer (2015) |