Universität Siegen
Naturwissenschaftlich-Technische Fakultät

Modulhandbuch für den Studiengang

Nanoscience and Nanotechnology

Master of Science (M.Sc.)

Änderungen vom 23.02.2021

Contents

1. Qualifikationsziele und Verlauf des Studiengangs

Aufbauend auf einem ersten Hochschulabschluss führt das Masterstudium zu einem Erwerb von analytischen und methodischen Kompetenzen im Bereich der Nanowissenschaft und Nanotechnologie. Die Absolventinnen und Absolventen des Studiengangs haben vertiefte Kenntnisse und Fähigkeiten im Bereich der physikalischen, chemischen und technologischen Teilfächer der Nanowissenschaft erworben. Damit sind sie in der Lage, die interdisziplinären Fragestellungen der Nanowissenschaften und Technologie erfolgreich zu bearbeiten.

Die Absolventinnen und Absolventen des Studiengangs werden für die universitäre und außeruniversitäre Grundlagenforschung im Bereich der Nanowissenschaften vorbereitet. Insbesondere sind sie, bedingt durch den interdisziplinären Charakter des Studiengangs, in der Lage, an den relevanten Schnittstellen der klassischen Felder Physik, Chemie und Ingenieurswissenschaften zu forschen. Sie sind für ein Promotionsstudium in einem der Teilfächer qualifiziert.
Die Absolventinnen und Absolventen erwerben grundlegende Kenntnisse in mehreren Teilaspekten der modernen Nanowissenschaften, die es ihnen ermöglichen, in Industrie- und Dienstleistungsunternehmen erfolgreich zu arbeiten.

Der Studiengang ist bewusst **departmentübergreifend** angelegt, um die ganze Breite der Nanowissenschaft und Nanotechnologie als Spiegelbild der MINT Fächer abzudecken. Der Studiengang ist als englischsprachiger und auf Forschung im internationalen Wettbewerb ausgerichteter Studiengang ein internationaler Studiengang.

Inhaltlich wird eine viersemestrige Ausbildung in den wesentlichen Aspekten der Nanowissenschaften angeboten:

Im 1. Semester gibt es dazu drei unterschiedliche Säulen, je nach Vorkenntnissen der Studierenden. Die Zuordnung zu den 3 Säulen erfolgt auf Grundlage der Vorkenntnisse der Studenten und erfolgt durch den Prüfungsausschuss. Damit erwerben die Studierenden die Grundlagen der jeweiligen anderen Teildisziplinen in den Nanowissenschaften. Gemeinsam ist im 1. Semester ein Seminar im Bereich der Forschung in den Nanowissenschaften, in dem u.a. auch auf wichtige globale Aspekte wie ein sicherer Umgang mit Nanotechnologie („Nanosafety“) eingegangen wird.

Im 2. Semester folgen die Pflichtkurse Nanochemistry, Photonic devices, und Physics of nanoelectronic devices. Zwei Praktika sind vorgesehen „Micro and Nanotechnology“ und „Nanosynthesis and Nanoanalytics“, die die experimentellen Methoden der Nanowissenschaft (incl. Nanotoxikologie) in Siegen abdecken.

Im 3. Semester haben die Studierenden die Möglichkeit aus einem breiten Wahlpflichtkatalog Vorlesungen zu wählen, zeitgleich findet ein Forschungspraktikum zur Vorbereitung auf die Masterarbeit in den Arbeitsgruppen statt.

Im 4. Semester wird schließlich die Masterarbeit angefertigt.

Based on a first university degree, the master's degree leads to the acquisition of analytical and methodological competences in the field of nanoscience and nanotechnology. The graduates of the course have acquired in-depth knowledge and skills in the field of physical, chemical and technological subdivisions of the nanoscience. They are therefore able to successfully deal with the interdisciplinary issues of nanoscience and nanotechnology.

The graduates of the course are prepared for university and non-university basic research in the field of nanoscience. In particular, due to the interdisciplinary character of the course, they are able to perform research at the relevant interfaces of the classical fields of physics, chemistry and engineering sciences. They are qualified for a PhD program in physics, chemistry or electrical engineering. The graduate students acquire basic knowledge in several aspects of the modern nanoscience, which enable them to work successfully in industrial and service companies.

The study program is designed to bridge the departments of physics, chemistry and engineering to cover the entire width of nanoscience and nanotechnology within the STEM subjects. The course is international as it is held in English and it aims for competitive international research.

In terms of content, four-semester training is offered in the essential aspects of nanoscience:

In the <u>1st semester</u> there are three different entry trainings, depending on the students' previous knowledge. Allocation of students to one of the entry training courses is made by the examination board. In this way, the students acquire the fundamentals of the respective other disciplines in the nanoscience. In the first semester, a seminar will be held in the field of nanoscience research and also on important global aspects such as a safe handling of nanotechnology ("nanosafety").

In the <u>2nd semester</u>, there will be compulsory courses in nanochemistry, photonic devices and physics of nanoelectronic devices. Two internships are planned: "Micro and Nanotechnology" and "Nanosynthesis and Nanoanalytics", which cover the experimental methods of nanoscience (including nanotoxicology) in Siegen.

In the <u>3rd semester</u>, students have the opportunity to choose from a wide list of compulsory elective courses, while a research internship is also being held to prepare for the master thesis in the working groups.

In the <u>4th semester</u>, the master's thesis is prepared within the research groups.

2. Structure of the master course Nanoscience and Nanotechnology

	Basic module for B. Sc. Physics		Basic module for B. Sc. Chemistry		Basic module for B. Sc. Engineering	
1. semester	General chemistry for physicists (incl. Lab course)	9CP	Quantum theory	6CP	Quantum theory	6CP
	Advanced solid-state physics	6CP	Solid-state physics	9CP	Solid-state physics	9CP
	Nanotechnology	6CP	Nanotechnology	6CP	General chemistry for engineers (incl. Lab course)	6CP
	Nano-research course (Seminar + Elective module)					9CP
2. semester	Nanochemistry					6CP
	Photonic devices					6CP
	Physics of nanoelectronic devices					6CP
	Lab course “Micro and Nanotechnology” (Processing: Litho, PVD, CVD, Etching, FIB, ….)					6CP
	Lab course “Nanosynthesis, nanosafety and nanoanalytics” (Nanostructure synthesis + Analytics: PL, Raman, X-Ray, Light Scattering, REM, TEM, ….)					6CP
3. semester	(free choice from course catalog)					6CP
	(free choice from course catalog)					6CP
	(free choice from course catalog)					6CP
	Research lab course (thesis prep.)					12CP
4. semester	Master thesis					30CP

(green)	Mandatory course
(orange)	Free choice from course catalogue
(blue)	Mandatory with free choice of research field
(red)	Lectures with nanoscience content which are offered only in semester 2 or 4

3. List of Modules

Nr	Course	Module ID	Semester	CP	Type	P.	Comment
1	Solid-state physics	SSP	1	9	Lecture	#	**Mandatory for Eng and Chem**
2	Advanced solid-state physics	ASSP	1	6	Lecture	#	Mandatory for Phys
3	Quantum theory	QT	1	6	Lecture	#	Mandatory for Eng/Chem, Elective for Phys
4	General chemistry for engineers	GChemI	1	6	Lecture/ Lab	#	Mandatory for Eng
5	General chemistry for physicists	GChemII	1	9	Lecture/ Lab	#	Mandatory for Phys.
6	Physics of nanoelectronic devices	NanoDev	2	6	Lecture	#	Mandatory for Phys/Chem/ Eng
7	Nano-research course	NRC	1	9	Lab/Lecture/Seminar	#	Mandatory for Phys/Chem/ Eng
8	Nanochemistry	NChem	2	6	Lecture	#	Mandatory for Phys/Chem/ Eng
9	Photonic devices	PhDev	2	6	Lecture	#	Mandatory for Phys/Chem/ Eng
10	Nanotechnology	NT	1	6	Lecture	#	Mandatory for Phys/Chem, Elective for Eng
11	Quantum field theory for solid-state physics	SST	1,3	6	Lecture	#	Elective
12	Nano-optics	NanOpt	1,3	6	Lecture	#	Elective
13	Scanning probe techniques for nanostructures	SPT	1,3	6	Lecture	#	Elective
14	Solid state physics of nanostructures	SSP-NS	1,3	6	Lecture	#	Elective
15	Modern methods of X-ray scattering	MMX	1,3	6	Lecture	#	Elective
16	Crystallography	Cryst	1,3	6	Lecture	#	Elective
17	Nanostructured materials	NanMat	1,3	6	Lecture	#	Elective
18	Applied optical spectroscopy	ApplSpec	1,3	6	Lecture	#	Elective
19	Physics and chemistry of interfaces	PC-Interf	2	6	Lecture	#	Elective
20	Physical chemistry of nanostructured and soft materials	PC-Nano	1,3	6	Lecture	#	Elective

21	Atomic force spectroscopy for materials and interfaces	AFM	2	6	Lecture	#	Elective
22	Methods and techniques of surface analysis	MTSA	3	6	Lecture	#	Elective

23	Polymer chemistry I – Properties of polymers	PolyChem I	1,3	6	Lecture	#	Elective
24	Polymer chemistry II – Syntheses of polymers	PolyChem II	1,3	6	Lecture	#	Elective
25	Advanced topics in polymer chemistry	AdvPolyChem	1,3	6	Lecture	#	Elective
26	Materials for energy storage and conversion	MaSC	3	6	Lecture	#	Elective
27	Advanced inorganic chemistry	AdvInorgChem	1, 3	6	Lecture	#	Elective
28	Magnetic resonance spectroscopy – Solid-state spectra analysis	NMR-I	1, 2, 3	6	Lecture	#	Elective
29	Magnetic resonance spectroscopy – Pulse methods	NMR-II	1, 2, 3	6	Lecture	#	Elective
30	Hybrid nanomaterials	HYBRID	1,3	6	Lecture	#	Elective
31	Microelectronics sensors	MICROSENS	1,3	6	Lecture	#	Elective
32	Analog integrated circuits	AINTCIRC	1,3	6	Lecture	#	Elective
33	Semiconductor electronics design	SEMELDES	1,3	6	Lecture	#	Elective
34	Nano-biophotonics	NanoBio	1,3	6	Lecture	#	Elective
35	Laboratory course “Micro and Nanotechnology”	LAB1	3	6	Lab-Course	#	Mandatory for Phys/Chem/Eng
36	Laboratory course “Nanosynthesis and Nanoanalytics”	LAB2	3	6	Lab-Course	#	Mandatory for Phys/Chem/Eng
37	Research lab course	RLC	4	12	Lab-Course	#	Mandatory for Phys/Chem/Eng
38	Master thesis	MT	4	30	Lab-Course	#	Mandatory for Phys/Chem/Eng

4. Modules description

Degree programme	Master *Nanoscience and Nanotechnology*
Course title, Topic	**Solid-state physics**
Subtitle (optional)	1
Module ID	SSP
Responsible lecturer	Prof. Dr. Carsten Busse
Teaching type	Lecture, tutorial
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Engineering or Chemistry
Semester	1
Credit points (CP)	9
Workload	Lecture: 60 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of solid state and nanophysics. The underlying physical principles and the mathematical formalism are understood, and the students can apply these to recent research topics of nanoscience.
Course description	Structural properties of solid states, binding energies, crystals, glasses, liquids, structure determination via X-ray scattering, phonons, electron gas, band structure, metal, insulator, semiconductor, thermal properties of electrons and phonons, spins and magnetism, exchange, ferro-, antiferro-, dia- and paramagnetism, magnetism in nanoscience
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%) or oral examination (100%)
Literature	Kittel, Ashcroft/Mermin, Ibach/Lüth and additional literature to be announced at the beginning of the module.

Degree programme	Master *Nanoscience and Nanotechnology*
Course title, Topic	**Advanced solid-state physics**
Subtitle (optional)	2
Module ID	ASSP
Responsible lecturer	Prof. Dr. Carsten Busse
Teaching type	Lecture, tutorial

Relation to curriculum	Mandatory basic module for students with a B.Sc. in Physics
Semester	1
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of solid-state and nano-physics and can apply these to recent research topics of nanoscience. Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Course description	Thermal properties of nanostructures, harmonic and anharmonic crystal, electronic properties of nanostructures, Sommerfeld-theory of metals, electron gas, quantum mechanics of electrons in potentials, Bloch-functions, Fermi-surfaces, energy bands, Brillouin zones, conductivity in metals, measurement of fermi-surfaces, homogeneous and inhomogeneous semiconductors, concepts of magnetism, exchange interaction, ferro/antiferro/dia/paramagnetism and applications in nanoscience, superconductivity
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%) or oral examination (100%)
Literature	Kittel, Ashcroft/Mermin, Ibach/Lüth and additional literature to be announced at the beginning of the module.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Quantum theory**
Subtitle (optional)	3
Module ID	QT
Responsible lecturer	Prof. Dr. Wolfgang Kilian
Teaching type	Lecture, tutorial
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry or a B.Sc. in Engineering, elective for students with a B.Sc. in Physics
Semester	1
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h

Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of quantum physics. The students are able to describe elementary quantum physical phenomena in terms of wave functions and interpret experimental outcomes in terms of probability theory.
Course description	• Key experiments for quantum phenomena. • Wave functions, energy and momentum in position representation, Schrödinger equation. • Eigenvalues, expectation value and uncertainty of observables. • Transmission/reflection and tunnelling. • Stationary states, harmonic oscillator. • Angular momentum quantization and spin. • Bosons and fermions, electron gas. • Basic effects of interactions and of finite temperature.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	To be announced in the first lecture

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**General chemistry for engineers (incl. laboratory course)**
Subtitle (optional)	4
Module ID	GChemI
Responsible lecturer	Prof. Dr. Holger Schönherr
Teaching type	Lecture, tutorial, Lab-course
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Engineering
Semester	1
Credit points (CP)	6
Workload	Lecture:30 h, tutorial: 30 h, lab course: 60 h, homework 60 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts of chemistry (e.g., structure-property relationships, donor-acceptor concept) and possess fundamental knowledge on the constitution of matter and laws of chemistry. They possess fundamental understanding of industrial chemical processes and chemical processes in nature. They are further accustomed to the main models in chemistry, they are able to observe, analyze, interpret and adequately report and summarize in written form dedicated natural phenomena.

	They possess fundamental competences in the planning, execution, analysis and evaluation of chemical experiments, they master fundamental techniques of chemical and analytical laboratory work. Their handling of chemicals is safe, sustainable and adequately cautious.
Course description	Principles of general chemistry. Atomic theory, electronic structure and properties of atoms, periodic table, ionic, covalent and metallic bonding, molecular orbitals, structures of molecules, chemical formulas, reaction equations, stoichiometry, energy balance of chemical reactions, chemical kinetics, chemical equilibrium, acids and bases, acid-base equilibria, gasses, liquids and solids, phase equilibria, solutions, electrochemistry, sustainable chemistry.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English, ability to work in a team, organization of a lab workplace.
Assessment method (Contribution)	Exam credits: Written examination (50%), lab course and tutorial (50%). Both parts must be passed separately.
Literature	Chemistry: The Central Science with Mastering Chemistry, Global Edition, Brown, LeMay, Bursten, Murphy, Woodward

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**General chemistry for physicists (incl. laboratory course)**
Subtitle (optional)	5
Module ID	GChem II
Responsible lecturer	Prof. Dr. Holger Schönherr
Teaching type	Lecture, tutorial
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Physics
Semester	1
Credit points (CP)	9
Workload	Lecture: 30 h, tutorial: 30 h, lab course: 90 h, homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts of chemistry (e.g. structure-property relationships, donor-acceptor concept), possess fundamental knowledge on the constitution of matter and laws of chemistry, know the most important fundamental concepts of synthetic chemistry and possess fundamental knowledge on selected classes of materials and relevant reactions. They possess fundamental understanding of industrial chemical processes and chemical processes in nature. They are further

	accustomed to the main models in chemistry, they are able to observe, analyze, interpret and adequately report and summarize in written form dedicated natural phenomena and chemical reactions. They possess fundamental competences in the planning, execution, analysis and evaluation of chemical experiments, they master fundamental techniques of chemical and analytical laboratory work. Their handling of chemicals is safe, sustainable and adequately cautious.
Course description	Principles of general chemistry. Atomic theory, electronic structure and properties of atoms, periodic table, ionic, covalent and metallic bonding, molecular orbitals, structures of molecules, chemical formulas, reaction equations, stoichiometry, energy balance of chemical reactions, chemical kinetics, chemical equilibrium, acids and bases, acid-base equilibria, gasses, liquids and solids, phase equilibria, solutions, electrochemistry, sustainable chemistry. Selected inorganic and organic reactions and reaction mechanisms as well as selected classes of materials. Selected spectroscopic, spectrometric and general methods for characterizing reactions and reaction products.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English, ability to work in a team, organization of a lab workplace.
Assessment method (Contribution)	Exam credits: Written examination (50%), lab course and tutorial (50%). Both parts must be passed separately.
Literature	Chemistry: The Central Science with Mastering Chemistry, Global Edition, Brown, LeMay, Bursten, Murphy, Woodward

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Physics of nanoelectronic devices**
Subtitle (optional)	6
Module ID	NanoDev
Responsible lecturer	Jun. Prof. Dr. Peter Modregger
Teaching type	Lecture, tutorial
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry, Physics or Engineering
Semester	2
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None

Learning outcomes / Competences	The students know the concepts and methods of solid-state physics and nanophysics and are able to understand concepts and operation of nanoelectronic devices. ese to recent research topics of nanoscience.
Course description	Crystal structure of solids, elastic properties, phonons, electronic band structure of solids, band structure of direct and indirect semiconductors, pn-junction, electronic devices as MOSFETs, solid state magnetism and magnetic devices. electronic band structure on the nanoscale, application in nano electronics.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%) or oral examination (100 %)
Literature	Kittel, Solid State Physics, Simon M. Sze, Physics of Semiconductor Devices, 3rd ed., Wiley-Interscience

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Nanoresearch Course**
Subtitle (optional)	7
Module ID	NRC
Responsible lecturer	Prof. Dr. Mario Agio
Teaching type	Seminar + Lecture
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry, Physics or Engineering
Semester	1
Credit points (CP)	9
Workload	Preparation of talk 30h, Seminar 30h, written summary 30h and one of the two following. Elective course : 30h, tutorial 30 h, homework 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know how to prepare and give a scientific talk. The students learn about the newest development in nanoscience and nanotechnology. The students learn the basics of scientific discussions and learn to write a summary of a science literature research.
Course description	Seminar with student talks about new topics in Nanoscience and Nanotechnology. Discussion. 15 Page written summary. Lecture from the elective module catalogue or Nanotechnology or Quantum theory.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills

	in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: 2 exams (Seminar 1/3 + elective course 2/3)
Literature	To be named in the first seminar and in the first lecture of the chosen course

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Nanochemistry**
Subtitle (optional)	8
Module ID	NChem
Responsible lecturer	Prof. Dr. Holger Schönherr
Teaching type	Lecture, tutorial
Relation to curriculum	Mandatory basic module for all students
Semester	2
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of Nanochemistry.
Course description	Principles of Nanochemistry. Synthesis and characterization of materials and nanomaterials (nanoparticles, nanorods, nanotubes, nanowires), chemical nanopatterning and nanostructuring, conventional and unconventional lithography, self-assembly principles, microspheres, micro- and mesoporous materials, self-assembly of molecules, layers, block copolymers and microscale objects, nanoscale machines and devices, bionanochemistry. Introduction to nanotoxicity and sustainable nanochemistry.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	*Nanochemistry*: *A Chemical Approach to Nanomaterials* Ozin, Arsenault, Cademartiri (RSC Publishing)

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Photonic devices**
Subtitle (optional)	9

Module ID	PhDev
Responsible lecturer	Prof. Dr. Peter Haring Bolivar, Prof. Dr. Mario Agio
Teaching type	Lecture, tutorial
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry, Physics or Engineering
Semester	2
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of photonic devices. They will be able to describe the basic electron-photon interaction phenomena and connect them to their use in photon detection devices on the nanoscale.
Course description	Electrons and photons, density of states, photon and electron transport, light-matter interaction, photonic materials, photonic crystals, plasmonics, nanocomposites, metamaterials, carrier motion and confinement, waveguides and couplers, quantum confinement, optical resonators, nanocavities, light emission, light detection, photodetectors, modulators, non-linear interactions, electro optic devices, nonlinear optical devices
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	To be named in the first lecture

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Nanotechnology**
Subtitle (optional)	10
Module ID	NT
Responsible lecturer	Prof. Dr. Peter Haring Bolivar
Teaching type	Lecture, lab-course
Relation to curriculum	mandatory basic module for students with a B.Sc. in Chemistry or Physics
Semester	1
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial/lab-course: 30 h, additional individual work of the student / homework time: 120 h

Prerequisites for participation	None
Learning outcomes / Competences	The students will be able to • ***describe*** the technological processes involved in the fabrication of nano- and microelectronic devices and circuits • ***compare*** alternative fabrication methods • ***apply*** the knowledge to specific device requirements through careful ***selection*** among a number of choices • ***assess*** pros and cons of different fabrication methods • ***combine*** fabrication methods to ***develop*** complex process flows for functional devices and circuits in a range of applications (e.g. transistors, solar cells, optoelectronics...)
Course description	Advanced course on the technological, physical and chemical methods used in modern semiconductor nanoelectronics fabrication.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (50%), lab course and tutorial (50%). Both parts must be passed separately. Written examination requires passing the lab-course.
Literature	• Plummer, Deal and Griffin, *Silicon VLSI Technology: Fundamentals, Practice and Modeling* • Simon M. Sze, *VLSI Technology*, McGraw-Hill • Hilleringmann, Silizium-Halbleitertechnologie: Grundlagen mikroelektronischer Integrationstechnik, Vieweg + Teubner, • Widmann, Mader, Technologie hochintegrierter Schaltung, Springer Verlag

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Quantum field theory for solid-state physics**
Subtitle (optional)	11
Module ID	SST
Responsible lecturer	Prof. Dr. Wolfgang Kilian
Teaching type	Lecture, tutorial
Relation to curriculum	Physics, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None

Learning outcomes / Competences	The students know the fundamental theoretical concepts and methods of solid-state physics. They are able to understand the many body quantum character of the physics involved and understand modern concepts of theoretical solid-state science.
Course description	• Linear oscillator chain, continuum limit, field operators, Fock space • One-particle and multi-particle interactions • Lagrangian, coherent-state path integral, bosons and fermions • Field integral, Matsubara formalism • Perturbation theory • Electron-electron interactions, models, Hartree-Fock and random-phase approximations • Cooper instability, BCS theory, excitations and phenomenology of superconductors • Ginzburg-Landau theory, Ising model, renormalization group for phase transitions
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	Altland/Simons "Condensed Matter Field Theory"; further literature to be announced at the beginning of the module

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Nano-optics**
Subtitle (optional)	12
Module ID	NanOpt
Responsible lecturer	Prof. Dr. Mario Agio
Teaching type	Lecture, tutorial
Relation to curriculum	Physics, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental theoretical and experimental concepts and methods of optics and nano-optics. They are able to understand the basic interaction mechanisms, the field concepts, the basics of resolution and modern concepts such as optical antennas and resonator on the nanoscale.

Course description	Theoretical foundations of optics, propagation and focusing of optical fields, resolution and localisation, nano-scale optical microscopy, optical interactions and quantum emitters, dipole emission near planar interfaces, photonic crystals and resonators, surface plasmon polaritons, optical antennas, optical forces
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written or oral examination (100%)
Literature	Principles of Nano-Optics (L. Novotny, B. Hecht), Molecular scattering and fluorescence in strongly confined optical fields (M. Agio)

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Scanning probe techniques for nanostructures.**
Subtitle (optional)	13
Module ID	TN
Responsible lecturer	Prof. Dr. Carsten Busse
Teaching type	Lecture, tutorial
Relation to curriculum	Physics, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of scanning probe techniques in nanoscience. They are able to describe the full range of different methods, the underlying physical effects, and to critically assess the experimental results that can be achieved.
Course description	Surface crystallography, quantum tunneling, near-field optics, tip-enhanced spectroscopies, scanning tunneling microscopy, scanning tunneling spectroscopy, atomic force microscopy, quasiparticle interference, atomic manipulation, surface preparation, preparation and characterization of sensors, image analysis, piezoelectric actuators, feedback loops, lock-in amplification
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.

Assessment method (Contribution)	Exam credits: Written examination (50%), tutorial (50%)
Literature	B. Voigtländer, Scanning Probe Microscopy, Springer E. Meyer, H. J. Hug, R. Bennewitz, Scanning Probe Microscopy, Springer C. J. Chen, Introduction to Scanning Tunneling Microscopy, Oxford University Press

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Solid-state physics of nanostructures**
Subtitle (optional)	14
Module ID	SSP-NS
Responsible lecturer	Prof. Dr. Carsten Busse
Teaching type	Lecture, tutorial
Relation to curriculum	Physics, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of solid-state physics with applications to nanoscience. They are able to describe elementary nanostructures, their physical properties and basic investigation methods.
Course description	Electronic structure and density of states in 3D, 2D, 1D and 0D; general solution of the Schrödinger equation in the potential well; quantum states in 1D and 0D nanostructures; surface crystallography; chemisorption and physisorption, heterogeneous catalysis; 2D materials (graphene, hexagonal boron nitride, transition metals of dichalcogenides); Dirac-like band structures; geometric structure and band structure of semiconductor nanostructures; excitons and charge carrier recombination; perovskite materials; molecular electronics; methods for the fabrication of nanostructures, thin films and two-dimensional materials, high resolution microscopic methods (STM, AFM, SEM, TEM), applications of nanostructures
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	To be announced in the first lecture

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Modern methods of X-ray scattering**
Subtitle (optional)	15
Module ID	MMX
Responsible lecturer	Jun. Prof. Dr. Peter Modregger
Teaching type	Lecture, tutorial
Relation to curriculum	Elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students should be able to • ***describe*** the fundamental concepts of X-ray science and scattering • ***connect*** X-ray science properties to investigation possibilities for nanoscience ***select and define*** relevant X-ray scattering techniques for different problems in the nano-sciences
Course description	X-ray sources, synchrotrons, X-ray free-electron lasers, interaction of X-rays/neutrons/electrons with matter, photo-absorption, cross sections, form factors, crystallography, correlation functions, structure factor, Debye Waller factor, small angle X-ray scattering, wide angle X-ray scattering, X-ray reflectivity, diffuse scattering, resonant magnetic scattering, coherence, speckles, imaging, phase retrieval, Fourier transform holography, ultrafast X-ray scattering methods
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (50%), tutorial (50%)
Literature	Jens-Als Nielsen, Warren, Guinier

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Crystallography**
Subtitle (optional)	16
Module ID	Cryst
Responsible lecturer	Jun. Prof. Dr. Peter Modregger

Teaching type	Lecture, tutorial
Relation to curriculum	Physics, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of crystallography.
Course description	Crystal forms, symmetries, space groups, symmetry operations, International tables of crystallography
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (50%), tutorial (50%)
Literature	Jens-Als Nielsen, Warren etc.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title	**Nanostructured materials**
Subtitle (optional)	17
Module ID	NanMat
Responsible lecturer	Prof. Dr. Claudia Wickleder
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students are able to recognize and evaluate advanced concepts and research results related to nanostructured materials. They know about current scientific developments.
Course description	Synthesis routes applied to nanostructured materials; physical properties of nanostructured materials; nanoparticles and thin films; quantum dots; form and structure; coated materials; metallic, semiconductor, dielectrics and oxide materials; applications of nanostructure materials: labels of biological

	structures, biochemical sensors, energy conversion like solar cells, displays and LEDs, data storage, photo catalysts
Interdisciplinary qualifications	Application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in a foreign language
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	Lecture, tutorial: selected scientific publications.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title	**Applied optical spectroscopy**
Subtitle (optional)	18
Module ID	ApplSpec
Responsible lecturer	Prof. Dr. Claudia Wickleder
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students are able to recognize and evaluate advanced concepts and research results related to optical spectroscopy. They know about current scientific developments.
Course description	Basic principles of optical spectroscopy; methods for the determination of optical properties; inorganic optical materials: metal organic and solid-state compounds, transition metal, lanthanides and s2 ions; synthesis routes, applications of optical materials: sensors, displays, solar cells, scintillators and security phosphors
Interdisciplinary qualifications	Application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in a foreign language
Assessment method (Contribution)	Exam credits: Oral presentation (50%), written examination (50%).
Literature	Lecture, tutorial: selected scientific publications.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Physics and chemistry of interfaces**

Subtitle (optional)	19
Module ID	PC-Interf
Responsible lecturer	Prof. Dr. Holger Schönherr
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	2
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of physical chemistry of surfaces and interfaces and can apply these to recent research topics of interfacial science.
Course description	Liquid surfaces, thermodynamics of interfaces, charged surfaces, surface forces, contact angle phenomena and wetting, solid surfaces, adsorption, surfactants, micelles, emulsions, foams, and thin films.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Study credits	Tutorial
Literature	Butt, Graf, Kappl, *Physics and Chemistry of Interfaces,* Butt, Kappl, *Surface and Interfacial Forces* and additional literature to be announced at the beginning of the module.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Physical chemistry of nanostructured soft materials**
Subtitle (optional)	20
Module ID	PC-Nano
Responsible lecturer	Prof. Dr. Holger Schönherr
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h

Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of physical chemistry of nanostructured materials and can apply these to recent research topics in this area.
Course description	Basics of nanostructured materials: Nanoscopic dimension, synthesis of soft nanostructures, approaches to characterize the structure of nanoscopic materials, metrology, approaches to investigate relevant properties of soft nanoscopic materials. Self-assembly and self-organized soft matter nanostructures: particles, capsules, tubes, functional nanomaterials.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Written examination (100%),
Study credits	Tutorial
Literature	Ozin, *Nanochemistry: A Chemical Approach to Nanomaterials,* Cademartiri, Ozin, *Concepts of Nanochemistry,* and additional literature to be announced at the beginning of the module.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Atomic force microscopy for materials and interface science**
Subtitle (optional)	21
Module ID	AFM
Responsible lecturer	Prof. Dr. Holger Schönherr
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	2
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts and methods of atomic force microscopy, the basics of intermolecular and surfaces forces and can apply these to recent research topics of interfacial science.
Course description	Atomic Force Microscopy principles, instrumentation, imaging, force measurements, data acquisition, data processing, artefacts; AFM measurement modi and underlying physics: contact, intermittent contact, non-contact, resonating force and resonance modes, electric and magnetic force mode; selected examples for

	AFM on soft matter, solid surfaces, thin films and measurements of molecular scale interaction forces.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%),
Study credits	Tutorial
Literature	Butt, Kappl, *Surface and Interfacial Forces,* Schönherr, Vancso *Scanning Force Microscopy of Polymers (Springer Laboratory)* and additional literature to be announced at the beginning of the module.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Methods and techniques of surface analysis**
Subtitle (optional)	22
Module ID	MTSA
Responsible lecturer	Prof. Dr. Holger Schönherr, Prof. Dr. Carsten Engelhard
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental concepts, methods and techniques of surface analysis and can apply these to recent research topics of interfacial and analytical chemical science.
Course description	Surface spectroscopy, including X-ray photoelectron spectroscopy, infrared spectroscopy, electron microscopy, atomic force microscopy, surface plasmon resonance, ellipsometry, quartz crystal microbalance, time-of-flight secondary ion mass spectrometry, laser ablation inductively coupled plasma mass spectrometry, glow discharge spectroscopy, laser induced breakdown spectroscopy, newly developed microscopic and spectroscopic techniques
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Written examination (100%)

Study credits	Tutorial
Literature	Vickerman, Gilmore, Surface Analysis: *The Principal Techniques* Butt, Graf, Kappl, *Physics and Chemistry of Interfaces* and additional literature to be announced at the beginning of the module.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Polymer chemistry I – Properties of polymers**
Subtitle (optional)	23
Module ID	PolyChem I
Responsible lecturer	Prof. Dr. Ulrich Jonas
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students are able to to recognize and evaluate molecular, structural and mechanical properties of macromolecules and polymers in in the solid, fluid and solution state.
Course description	Structure of macromolecules: constitution, configuration (tacticity), conformation (macro conformation, helix formation); molecular weights, -distributions; shape of individual macromolecules: coils, rods, macromolecules in solution, phase separation, fractionation; amorphous (glassy) state; crystalline state, chain folding, morphology, thermal transitions: melting, crystallisation, glass transition; viscoelastic behaviour of polymers; basics of processing. Methods: size exclusion chromatography, thermal analysis, rheology, dynamic-mechanical thermal analysis, stress-strain behaviour, optical methods, processing. Aspects of sustainability in polymer processing and recycling will be discussed.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	R. J. Young, P. A. Lovell; "Introduction to Polymers", 3nd ed., Chapman & Hall 2011

Degree programme	Master *Nanoscience and Nanotechnology*
Course title, Topic	**Polymer chemistry II – Syntheses of polymers**
Subtitle (optional)	24
Module ID	PolyChem II
Responsible lecturer	Prof. Dr. Ulrich Jonas
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	2,4
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	Successful participation in Applied Chemistry I / II, Macromolecular Chemistry, participation in Advanced Organic Chemistry I
Learning outcomes / Competences	The students are able to recognize and evaluate molecular, structural and mechanical properties of macromolecules and polymers in in the solid, fluid and solution state.
Course description	Basic definitions of polymer chemistry, conditions of polymerisation reactions, free radical polymerisation, ionic polymerisation, stereo specific polymerisation with transition metal catalysts, copolymerisation, step polycondenstion, step polyaddition, reactions on polymers. Aspects of sustainability in polymer synthesis with monomers from natural sources and biodegradable polymers will be discussed.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination (100%)
Literature	R. J. Young, P. A. Lovell; "Introduction to Polymers", 3nd ed., Chapman & Hall 2011

Degree programme	Master *Nanoscience and Nanotechnology*
Course title, Topic	**Advanced topics in polymer chemistry**
Subtitle (optional)	25
Module ID	AdvPolyChem
Responsible lecturer	Prof. Dr. Ulrich Jonas
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective

Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students will get an overview about current topics in polymer sciences and are able to recognize and evaluate the potential of macromolecular chemistry and polymeric materials for nanoscience and nanotechnology.
Course description	Special topics in the field of Polymer Chemistry. Surface chemistry of macromolecular materials, soft lithography with macromolecular materials, polymeric hydrogels, hierarchical structures with polymeric colloidal particles.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written examination or oral presentation (100%)
Literature	Relevant literature will be distributed in the lecture

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Materials for energy storage and conversion**
Subtitle (optional)	26
Module ID	MaSC
Responsible lecturer	Prof. Dr. Jörn Schmedt auf der Günne
Teaching type	Lecture, tutorial
Relation to curriculum	Chemistry, elective
Semester	2 or 3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students are able to recognize and evaluate advanced concepts and research results related to materials for energy storage. They know about current scientific developments.
Course description	Classical synthesis routes applied to materials for energy storage and conversion; synthesis of nanomaterials using top-down and bottom-up strategies; materials and devices for energy storage and conversion; characterization of relevant properties including impedance spectroscopy, cyclic voltammetry, band-structures,

	calculation of band-structures; texture and its influence on materials properties; models for ionic conduction; phase-change materials
Interdisciplinary qualifications	Application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Oral or written examination (100%)
Literature	Lecture, tutorial, seminar: selected scientific publications.

Degree programme	**Master Nanoscience and Nanotechnology**
Course title, Topic	Advanced inorganic chemistry
Subtitle (optional)	27
Module ID	AdvInorgChem
Responsible lecturer	Prof. Dr. Jörn Schmedt auf der Günne, Prof. Claudia Wickleder
Teaching type	Lecture, tutorial
Semester	1 or 3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The students are able to name and describe syntheses of inorganic compounds, to classify and to characterize inorganic compounds with respect to physical and chemical criteria, to evaluate properties of inorganic compounds and to suggest appropriate physical methods to measure these properties. The students are able to summarize important aspects of a broader topic orally and in written form.
Course description	Chemical and physical crystal growth- and preparation- methods, solid state-, molecular-, cluster- and coordination- compounds, thermodynamic and kinetic aspects of solid-state reactions and of stabilities of compounds, advanced models of chemical bonding, structures of molecules and crystal structures of important classes of solids, modern physical methods to investigate and to characterize solids.
Interdisciplinary qualifications	Application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Written examination (75%), tutorial (25%)
Literature	Lecture, Tutorial, Seminar: Shriver, Atkins, *Inorganic Chemistry*; Riedel: *Modern Inorganic Chemistry*, special textbooks and selected publications.

Degree programme	**Master Nanoscience and Nanotechnology**

Course title, Topic	Resonance spectroscopy - Solid-state spectra analysis
Subtitle (optional)	28
Module ID	NMR-I
Responsible lecturer	Prof. Dr. Jörn Schmedt auf der Günne
Teaching type	Lecture, tutorial
Semester	2 or 3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The students are able to recognize and evaluate concepts of magnetic resonance solid-state spectroscopy. They are able to apply methods and concepts to questions in nano-chemistry. They know how magnetic resonance spectra are a function of the structure and dynamics of nanoscale materials. They know about current scientific developments.
Course description	Characterization (structure, ion conductivity) of materials by NMR; computer simulation of spectra; relaxation and dynamics; usage of a virtual spectrometer; analysis of experimental data
Interdisciplinary qualifications	Application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Oral or written examination (100%)
Literature	Lecture, tutorial, seminar: selected scientific publications.

Degree programme	**Master Nanoscience and Nanotechnology**
Course title, Topic	Magnetic resonance spectroscopy – Pulse methods
Subtitle (optional)	29
Module ID	NMR-II
Responsible lecturer	Prof. Dr. Jörn Schmedt auf der Günne
Teaching type	Lecture, tutorial
Semester	2 or 3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The students are able to recognize and evaluate advanced concepts of magnetic resonance solid-state spectroscopy. They are able to apply methods and concepts to questions in nano-chemistry. They know different pulsed experiments and understand how these can elucidate structure and dynamics of solids. They know about current scientific developments.

Course description	Characterization (porosity, structure, ion conductivity) of materials by advanced NMR methods; computer simulation of pulse sequences; multidimensional spectroscopy; product operator formalism; data analysis of pulse sequences (REDOR, MQMAS, ...)
Interdisciplinary qualifications	Application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Oral or written examination (100%)
Literature	Lecture, tutorial, seminar**:** selected scientific publications.

Degree programme	**Master Nanoscience and Nanotechnology**
Course title, Topic	Hybrid nanomaterials
Subtitle (optional)	30
Module ID	Hybrid
Responsible lecturer	Prof. Dr.-Ing. Manuela Killian
Teaching type	Lecture, tutorial, laboratory
Semester	3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 15 h, laboratory: 15 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The students know the fundamental concepts and methods of hybrid inorganic-organic nanostructured materials and can apply these to recent research topics in this area.
Course description	Concepts of hybrid nanostructured materials: Hybrids in nature and technology; inorganic hybrids (alloys, layered systems, decoration...); organic-inorganic hybrids, molecular adhesion, nano-tailoring of surface chemistry, self-assembly; characterization of nanostructured hybrid materials; application in (e.g.) energy conversion, catalysis, nano-bio applications.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Oral or written examination (100%)
Literature	Vargas-Bernal, Hybrid Nanomaterials, Kalia, Haldorai, Organic-Inorganic Hybrid Nanomaterials, and additional literature to be announced at the beginning of the module.

Degree programme	**Master Nanoscience and Nanotechnology**
Course title, Topic	Microelectronic sensors
Subtitle (optional)	31

Module ID	MicroSens
Responsible lecturer	Prof. Dr.-Ing. Bhaskar Choubey
Teaching type	Lecture, tutorial, laboratory
Semester	3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 15 h, laboratory: 15 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The course is dedicated to integration of physical sensors with microelectronic circuits. The students will first understand the concepts of physical measurements as well as various sources of errors. They will be able to analyse and differentiate between different type of sensors for the same physical phenomenon. They will also learn advanced circuit concepts to interface these sensors. Finally, they will analyse advanced concepts of at least two different sensing systems. The first will be optical sensors, particularly CMOS image sensors and its various circuits and applications. The second will be microelectromechanical sensors, including concepts of mechanical and chemical sensing along with their integration with microelectronic circuits.
Course description	• Physical quantities and their measurement • Measurement Errors and concepts of ○ Sensitivity/ Precision/ Resolution/ Accuracy/ Bias/random errors ○ Calibration standards • Optical Sensors - CCD and CMOS image sensors • Microelectromechanical sensors - types, fabrication methods, simulation and design, testing • Sensor interface circuits and their physical implementations
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Oral or written examination (100%)
Literature	Relevant literature will be distributed in the course

Degree programme	**Master Nanoscience and Nanotechnology**
Course title, Topic	Analog integrated circuits
Subtitle (optional)	32
Module ID	AIntCirc
Responsible lecturer	Prof. Dr.-Ing. Bhaskar Choubey
Teaching type	Lecture, tutorial
Semester	3

Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 15 h, laboratory: 15 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The learning outcomes of the course are to provide the student with an ability to: • Design analogue circuits in a CMOS process by calculating the required properties of various transistors • Analyse single transistor circuits and calculate its performance parameters. • Use MOSFETs as building blocks of complex large analogue systems • Understand signal amplification and limitations of real-world amplifiers • Calculate and analyse the effects of noise in electronic circuits. Use filters to reduce the effect of noise • f. Design complex analogue circuits for interfacing sensors
Course description	• Introduction: Moore's Law, SPICE, MOSFETs characteristics • Building Blocks: Single stage amplifiers, Mirrors, sources and loads, Output stages and power amplifiers • Multi-stage amplifiers: Cascode and cascade circuits, Op-amp design • Op-amp characteristics: Frequency and transient responses, Stability and compensation, CMRR, PSRR and slew rate, Common Mode Feedback • Noise: Sources, Reduction techniques • Sensor interface circuits: Active filters, Data Converters, Oscillators Circuits
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Oral or written examination (100%)
Literature	Relevant literature will be distributed in the course

Degree programme	**Master Nanoscience and Nanotechnology**
Course title, Topic	Semiconductor electronics design
Subtitle (optional)	33
Module ID	SemElDes
Responsible lecturer	Prof. Dr.-Ing. Bhaskar Choubey
Teaching type	Lecture, tutorial
Semester	3
Credit points (CP)	6

Workload	Lecture: 30 h, laboratory: 30 h, additional individual work of the student / homework time: 120 h
Learning outcomes / Competences	The learning outcomes of the course Semiconductor Electronics Design is to • Understand the design principles used in electronic systems • Acquire working knowledge of computer-based modelling, simulation and testing tools used in electronics design • Understand manufacturing processes and supply chain of electronic components needed in design. • Understand properties of materials used in integrated systems • Understand building blocks of integrated electronic systems • Emphasize problem definition, design conceptualization, modelling, approximation techniques, optimization and prototyping in the context in microelectronic systems
Course description	In this course, the elementary design processes in the microelectronics industry are considered. The students will first be taught lecture-based courses followed advanced learning of software tools. It will consist of • Design approaches – top-down, bottom-up, divide and conquer, structured design, object-oriented design • Manufacturing process for VLSI • Materials - Micro-electronic properties • Analog and digital building blocks of integrated electronic systems • Modelling and simulation methods including SPICE Practical skills in an advanced design tool leading to a full system design with communication, analogue and digital components
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English
Assessment method (Contribution)	Exam credits: Written and practical examination (100%)
Literature	Relevant literature will be distributed in the course

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Nano-biophotonics**
Subtitle (optional)	34
Module ID	NanoBio
Responsible lecturer	Prof. Dr. Mario Agio, Prof. Dr. Holger Schönherr, Prof. Dr. Haring Bolivar
Teaching type	Lecture, tutorial
Relation to curriculum	Physics, Chemistry, Engineering, Elective

Semester	1,3
Credit points (CP)	6
Workload	Lecture: 30 h, tutorial: 30 h, additional individual work of the student / homework time: 120 h
Prerequisites for participation	None
Learning outcomes / Competences	The students know and are capable of advanced concepts related to nano-biophotonics. You are familiar with current scientific developments.
Course description	Light-matter interaction, light microscopy, molecular spectroscopy, biological markers and functionalization methods DNA technology, cells and biological tissue, nanophotonics, fluorescence amplification, surface-enhanced Raman scattering, high-resolution optical microscopy, atomic force microscopy.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Written or oral examination (100%)
Literature	Principles of Nano-Optics (L. Novotny, B. Hecht), Introduction to Biophotonics (P. Prasad) and teacher's material.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Laboratory course "Micro and Nanotechnology"**
Subtitle (optional)	35
Module ID	LAB1
Responsible lecturer	Prof Dr. Peter Haring Bolivar
Teaching type	Lab-Course
Relation to curriculum	Mandatory basic module for students with aB.Sc. in Chemistry, Physics or Engineering
Semester	2
Credit points (CP)	6
Workload	60 h work laboratory, 60 h preparation, 60 h homework
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental experimental concepts and methods of Nanoscience and Nanotechnology used at the University of Siegen.
Course description	Laboratory course for nanoscale processing: Litho, PVD, CVD, Etching, FIB and others.
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills

	in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Lab Course (100%)
Literature	Relevant literature will be distributed in the course

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Laboratory course "Nanosynthesis, Nanosafety and Nanoanalytics"**
Subtitle (optional)	36
Module ID	LAB2
Responsible lecturer	Prof. Dr. Peter Haring Bolivar, Prof. Dr. Claudia Wickleder, Prof. Dr. Carsten Busse
Teaching type	Lab-Course
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry, Physics or Engineering
Semester	2
Credit points (CP)	6
Workload	60 h work laboratory, 60 h preparation, 60 h homework
Prerequisites for participation	None
Learning outcomes / Competences	The students know the fundamental experimental concepts and methods of Nanoscience and Nanotechnology used at the University of Siegen. The students learn the basics aspects of safety involved with nanoscience and technology.
Course description	Laboratory course for nanostructure synthesis and analytics including aspects of nanosafety. Synthesis of nanostructures and their characterization by means of Raman, X-Ray, dynamic light scattering, REM, TEM, ….
Interdisciplinary qualifications	Ability to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter- and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method (Contribution)	Exam credits: Lab Course (100%)
Literature	Relevant literature will be distributed in the course

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Research lab course**
Subtitle (optional)	37
Module ID	RLC
Responsible lecturer	Board of examiners

Teaching type	Lab-Course
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry, Physics or Engineering
Semester	3
Credit points (CP)	12
Workload	Seminar: 90 h, Lab course: 120 h, additional individual work of the student / homework time: 60 h.
Prerequisites for participation	Passing of all modules of the preceding semesters
Learning outcomes / Competences	Students apply scientific strategies of the chosen research topic. Students are able to design and perform experiments based on literature search on their own.
Course description	Literature search, elaboration of measurement/synthesis/technological strategies, involvement in current research topics, lab reports and critical evaluation of results.
Interdisciplinary qualifications	Interdisciplinary assessment and evaluation, literature survey, und techniques of presentation, organization and management of a scientific project, ability to work in an international (and intercultural) team, presentation of the results of a scientific investigation to an expert audience, debating and discussing in English, database literature search, analysis of scientific papers, presentation techniques.
Assessment method (Contribution)	Evaluation of the report by two experts, i.e., university professors (100 %).
Literature	To be announced by the respective professional supervisor.

Degree programme	**Master *Nanoscience and Nanotechnology***
Course title, Topic	**Master thesis**
Subtitle (optional)	38
Module ID	MT
Responsible lecturer	Board of examiners
Teaching type	Lab-Course
Relation to curriculum	Mandatory basic module for students with a B.Sc. in Chemistry, Physics or Engineering
Semester	4
Credit points (CP)	30
Workload	6 months
Prerequisites for participation	Passing of all modules of the preceding semesters
Learning outcomes / Competences	The students are able to choose a current research topic from a selected area of physics, chemistry or engineering. They are able to manage and document their own research project and present

	their results in front of an expert audience. The students know and are able to use adequate working methods and instrument for scientific research and have comprehensive competences in a scientific perspective.
Course description	Organization and elaboration of a research project.
Interdisciplinary qualifications	Interdisciplinary assessment and evaluation, literature survey, organization and management of a scientific project, ability to work in international (and intercultural) research groups, presentation of the results of a scientific investigation to an expert audience, debating and discussing in English.
Assessment method (Contribution)	Evaluation of the thesis by two experts, i.e., university professors (100 %).
Literature	To be announced by the respective professional supervisor.