Course Package

Characterization and Fabrication of Nanostructures – Q2

Name module	Characterization and Fabrication of Nanostructures – Q2
Educational programme	MSc Nanotechnology
Period	First quartile of the second semester – Q2
Study load	30 ECTS
Coordinator	B. Schouwstra

Characterization and Fabrication of Nanostructures			
Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
		Electives: choose 15 EC	
		Inorganic Materials Science - 193700040 (5 EC)	
		Bionanotechnology – 193400111 (5 EC)	
		Nano-Fluidics – 193400121 (5 EC)	
		Micro Electro Mechanical Systems Design - 191211300 (5 EC)	
		Surfaces and Thin Layers - 193550020 (5 EC)	
		Biomedical Signal Acquisition – 191210720 (5 EC)	
		Nanophotonics – 201100074 (5 EC)	

Interesting for: BSc students of Chemical Engineering, Chemistry, Applied Physics, Electrical Engineering, and Nanotechnology.

Required preliminary knowledge: Basics of Physical Chemistry; Organic and Inorganic Chemistry; Materials Science and Molecular Biology; Solid State Physics and Quantum Mechanics (Quantum Physics, Level B2); Chemistry & Technology; Thermodynamics; Capillarity and Wetting Phenomena; Advanced Fluid Dynamics; Statistical Mechanics; Optics; Electrodynamics.

Electives: choose 15 EC

193700040 - Inorganic Materials Science

The key method of instruction/learning is based on student-driven learning to gain the necessary fundamental and advanced knowledge, skills, and attitude in selected example cases addressing the relationship between the structure/composition and properties of advanced inorganic materials. Advanced materials are novel or modified materials with new or enhanced properties that help cope with the increased demands in technological applications. These are, amongst others, electronic applications (dielectrics and ferroelectrics), optical applications (lightharvesting materials and transparent conducting oxides, magnetic applications (different types of magnetic materials) and materials for energy production and storage (ionic conductors, mixed electronic/ionic conductors, and optoelectronic materials). These example cases are selected to cover a large breadth from basic materials science to (sustainability-related) application cases. The course consists of multiple parts, including group theory of crystal symmetry, Landau theory (e.g., ferroelectrics), Optoelectronic materials and defect chemistry (e.g., ionic and electronic transport properties),. Students are offered a choice regarding some of the topics. Each part contributes to the overarching learning objective and student-driven learning approach. All of these topics will be discussed using recent scientific articles to enable students to discuss advanced materials discoveries and make materials design choices for various applications.

193400111 - **Bionanotechnology**

Bionanotechnology is a field of research and applications that sits at the interface between nanotechnology on the one hand and life sciences on the other.

This course includes:

- An introduction to the field of bionanotechnology field
- Basics of nanobiology, including structure and function of DNA/RNA, DNA supercoiling, chromatin structure, structure and function of proteins, lipids, membranes, molecular motors, biological cells
- (Biological) nanoparticles, including gene therapy and DNA nanoparticles, inorganic and iron oxide nanoparticles, quantum dots, the unfamiliar world at the nanoscale, molecular interactions, Brownian motion, and diffusion
- Methods and techniques to study biology at the nanoscale, including fluorescence microscopy and other fluorescence-based techniques, nanoscopy methods, scanning probe microscopy (AFM), single-molecule force spectroscopy, elasticity mapping, optical tweezers, and magnetic tweezers.
- Writing of a comprehensive essay on the applications of nanobiotechnology, based on a short literature study.

193400121 - Nano-Fluidics

This course gives an introduction into Nano fluidics, considering fundamental aspects, intrinsic length scales and geometry. A number of different selected topics in the field of Nano fluidics are discussed, such as:

- basic fluid dynamics for micro- a Nanochannelsls
- solid-liquid interfaces (interactions, adsorption/desorption)
- electric double layer theory
- hydrodynamics at small scales (laminar flow, slip versus no-slip, mixing)
- 3-phase systems (capillary forces, super hydrophobicity)
- electro kinetic effects (electroosmotic pumping, electro viscous effect)
- electrophoresis and separation techniques
- (Nano)colloidal particles and colloidal assembly

191211300 - **Micro Electro Mechanical Systems Design**

Micro-electro-mechanical systems design addresses the systematic design of silicon-based electro-micromechanical devices and systems in a step-wise fashion. In the lectures, different design principles are derived from the theory of elastic mechanics, transducer science, resonance and practised in exercise sessions. A major part of the course is the design lab in which the students design and test a device of their own choice which is realized in a foundry process offered by the MCS/IDS group.

In the design lab, silicon-based micromechanical devices are designed in different phases, starting with conceptual design, through physical design (modelling and dimensioning), all the way to mask design.

Typical topics: Elastic mechanics of beams and membranes; actuator theory including electrostatic actuation, design of electrostatic motors; sensor transduction and read-out electronics, design of acceleration -, angular velocity -, force -, and pressure sensors; resonance and quality factor; adhesion, stiction and friction in micro and nano-systems.

193550020 - Surfaces and Thin Layers

The structure and (electronic) properties of both clean and adsorbate covered surfaces are described. The most common tools to study these phenomena, diffraction and scanning probe techniques are introduced in relation to the measured results. The adsorption and desorption of species from surfaces are described. Growth of thin films is an important part of this field and the thermodynamic and kinetic aspects of growth are discussed. The electronic structure of surfaces and thin films in relation to their properties is described. This course is part of the track Materials Science and is compulsory for students of this track.

191210720 - Biomedical Signal Acquisition

The electrochemical detection methods form a beautiful comprehensive part of this course: starting from electrochemical processes at an electrode and the subsequent mass transport phenomena result in the three basic operational principles (potentiometry, amperometry and conductometry). When the relation between the variable to be determined (ionic species and/or its concentration) and the measured quantity (voltage, current or conductance) is known, the relevant examples follow: the oxygen electrode (Clark electrode), the carbon dioxide sensor (Severinghaus principle) and the pH sensors (glass electrode). Additionally, other chemical biosensors like the glucose sensor, and biosensors based on optical detection principles are treated. The treatment of physical sensor systems is guided by the biomedical application: blood pressure and flow, lung volume and capacity. A bridge to the course Lab-on-a-Chip is formed by some examples of micro Total Analysis Systems, of which the detector is based on one of the mentioned sensor principles.

This course is open for TM, MBE, APH, NANO and EE students. General knowledge from your bachelor programs is required. For TM students, this course bridges the gap between biophysiology and biomedical signal processing and -analysis. This course consists of 12 lectures, where you actively participate in discussions to reach the learning objectives.. You will write your critical review paper in teams of two students to train and improve your knowledge and understanding via the original papers you have to review. Moreover, a 4-hr practical project concerning synchronous sensor data retrieval into a computer is one of the instructional modes of this course.

201100074 - Nanophotonics

The following topics are treated:

1. Light scattering: Diffraction (Babinet), Rayleigh and Mie theory and point scatterers.
2. Dispersion: Effective medium theory, Kramers-Kronig relations.
3. Random media: Light diffusion, Coherent backscattering, Anderson localization.
4. Photonic band gap crystals: Optical Bragg diffraction, Bloch waves, Bandstructures, Local density of states, Photonic band gap cavities.
5. Optical wavefront shaping: Optimization, Mesoscopics.
6. Fabrication methods.
7. Applications: Lighting, White LEDs, High-resolution imaging, Non-conventional microscopy.

Learning objectives After following the course, the student	**Way of assessment**	**Level**	**Weighing**
Can apply concepts of diffraction, dispersion, wave scattering in calculations	Homework assignments	Comprehend, describe, apply.	30%
	Homework assignments	Understand, explain, illustrate	10%

The modules are tentative and subject to change. Please check the website regularly.
Timetable clashes may occur.

Can understand the origin of Kramers-Kronig relations and multipole scattering expansions.			
Can perform a simple light scattering experiment and analyze and report the results taking into account the acquired skills	Report	Understand, explain, apply, calculate, draw conclusions, propose, synthesize	40%
Can understand basic concepts of photonic crystals and scattering media such as photonic bandgaps and the relation to the Bloch theorem, scattering and transport mean free paths	Homework assignments	Understand, explain, apply, calculate, draw conclusions	20%

There are take-home assignments on theory, and on the experiments (“practica”). While cooperation between students is encouraged, all assignments must be handed in individually. In some cases (e.g., if international experts are visiting or simultaneous relevant scientific meeting occurs) a poster presentation or the writing of a summary of a colloquium talk may substitute for conventional assignments.