# Course Package

# Characterization of Nanostructures

| Characterization of Nanostructures | First semester | 30.0 EC |
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*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, Introduction to Quantum Mechanics. Solid State Physics and Quantum Mechanics (Quantum Physics, Level B2).

This module consists of the following courses:

**Characterization of Nanostructures**
This module includes a lecture part (5 EC) and an additional project part (2,5 EC). Within the lecture part a wide range of modern, state-of-the-art analytical techniques and tools (microscopy, spectroscopy and diffraction methods) to characterize structure and properties of nanostructures will introduced and discussed. The central goal is to provide a fundamental understanding of various aspects of molecular, nanoscale and continuum (macroscopic) scale characterization that are essential for the study of nanostructures.
In the project part you are going to study how biological nanostructures can be characterized. To this end you will, in a small team of students, perform a detailed analysis of a peer-reviewed scientific paper that describes research related to characterization of biological systems at the nanoscale.

**Nano-lab: Fabrication & Characterization**
The objective of this practical course is to train practical experimental skills that are needed in an interdisciplinary research laboratory environment in the field of nanotechnology. It includes skills needed for the fabrication of nanostructures by means of top-down as well bottom-up techniques and the characterization of nanostructures with various techniques. This course will provide hands-on training in nanofabrication as well as characterization of realized nanostructures in the NanoLab cleanroom as well as at a number of research group labs.
Students will work in groups of 3 and each group performs 3 nanolithography experiments (each experiment lasts 1 day in the cleanroom), which are listed in Table 2. The module starts with an introductory lecture on the fundamentals of three nanolithography techniques, i.e. electron-beam lithography (EBL), laser-interference lithography (LIL) and displacement Talbot lithography (DTL). Subsequently, by means of these lithography techniques nanometer-sized features will be fabricated in the NanoLab cleanroom.

**Nanoscience**
This course is an introduction to the Fundamentals of nanoscience. The following aspects will be discussed; fundamentals of nanoscopic physics, introduction to Nanoelectronics (top-down vs bottom-up approach, relevant length scales), and wave/particle duality, wave functions, wave packets and Heisenberg uncertainty relations. In addition, free and confined electrons, free electron model, density of states, band theory (periodic potential), tunnel junctions/resonant tunneling, single electron tunneling and electronic structure of quantum dots, quantum wires and quantum wells and their transport properties will be treated. Also, coulomb blockade and single electron transistor will be discussed.

*The modules are tentative and subject to change. Please check the website regularly.*

**Fabrication of Nanostructures**
The course will introduce the techniques that are available for creating nanostructures, both top-down (e.g. optical lithography techniques) as well as bottom-up (self-assembly/nanochemistry). The course is therefore divided into two sections: S1. Technology (teacher: Alexey Kovalgin); S2. Nanochemistry (teacher: Jurriaan Huskens)
S1. The course provides a general introduction to the field of manufacturing technology of microsystems. The emphasis is put on the fabrication steps. The most commonly applied steps (techniques) are treated. The techniques having the same main goal are compared, their advantages and disadvantages are discussed, the choices of suitable techniques for the particular application/device are questioned. The important criteria (e.g. film properties, uniformity, the costs, the efficiency, the reproducibility and the reliability), to compare the different techniques, are demonstrated. It is shown how fabrication steps can be combined in a process flow to fabricate a functional microsystem. Several examples are given where the integration processes to fabricate microsystems are treated in an introductory manner, including realization of microprocessors, microfluidic systems, lab-on-a-chip, MEMS and nanoelectronic (spintronic) devices.Two main blocks are given. Block 1 considers the basics (main building blocks) of microtechnology and includes introduction and history, substrates and wafers, modification of materials, lithography, film deposition, wet and dry etching, wafer bonding and packaging. Block 2 consists of guest lectures and covers different application areas of the main building blocks to realize microsystems in the field of integrated circuits, biochips, nanoelectronics, spintronics, MEMS, and micro-fluidics.
S2 (Nanochemistry): topics: 1. Introduction to Nanochemistry; 2. Gold; 3. Quantum dots; 4. Silica; 5. Polydimethylsiloxane; 6. Iron oxide; 7. Carbon.

***Choice (2 out of 3):***

- **Nano-Electronics:** Nanoelectronics comprises the study of the electronic and magnetic properties of systems with critical dimensions in the nanoregime. Hybrid inorganic-organic electronics, spin electronics and quantum electronics form important subfields of nanoelectronics and are being discussed in this course. For those who want to get a thorough introduction into the new exciting directions that will contribute to future electronics, this course is indispensable. The course consists of lectures, assessments and a project. In the project, a small research proposal is written on a theme related to the course. The proposal is presented in written and oral form and graded by the lecturers.
- **Nanomedicine**: Nanomedicine is one of the most dynamic fields, which holds a high potential to make a huge impact on the medical science. Nanomedicine is in general defined as medical applications of nanotechnology. In recent years, nanotechnologies have been applied for drug delivery, imaging/diagnostics, biosensing, in vitro diagnostics, and tissue engineering. One of the largest areas for nanomedicine is the drug delivery/targeting. Conventional medicine, which are either administered orally or with injections, are not always successful for achieving the desired therapeutic effects but rather show high side effects. Therefore, novel drug delivery systems are highly crucial to develop, using which the drugs can be specially delivered at the targeted site or even to the specific cell types. Using these novel approaches, high therapeutic effects and low/no side effects can be achieved. A large part of the course will be devoted to the drug delivery. Besides drug delivery, nanomedicine includes applications of nanomaterials for imaging and diagnostics as well as theranostics (therapeutics + diagnostics), which will be covered up during this course. Applications to drug delivery and imaging are mostly related to applications of nanotechnologies in vivo. In addition, nanomedicine also covers up in vitro applications such as diagnostics using biosensing techniques and microfluidics. Students will also write a research proposal during this course on an assigned topic of nanomedicine, which allows them to further develop their knowledge on this subject. Altogether this course provides a broader and in depth understanding of the emerging field of nanomedicine.
- **Lab on a Chip:** The Lab on a Chip course will take the student to the world of miniaturised systems used in various fields of chemistry and life sciences. A "Lab-on-a-Chip" consists of electrical, fluidic,

and optical functions integrated in a microsystem, and has applications in (bio)chemical and medical fields. The core of the lab-on-a-chip system is a microfluidic channel structure, through which nanoliter amounts of liquids with dissolved molecules are propelled by hydraulic, electrokinetic or surface forces. The fluidic structures are machined in materials like fused silica, borofloat glass, or polymers. The course will treat all relevant aspects of such microsystems in a number of problem-based learning sessions. Microfluidic theoretical principles are treated with emphasis on the transport of liquid and dissolved molecules in microsystems and molecular separation. This is followed by an introduction in aspects of microfabrication. Electrochemical and optical detection methods are subsequently treated. Then the manipulation of cells in microfluidic systems is considered. The course finishes with a written exam and a written case study.