

# Course Package

## Characterization and Fabrication of Nanostructures – Q1 + Q2

Name module	Characterization and Fabrication of Nanostructures – Q1 + Q2
Educational programme	MSc Nanotechnology
Period	First semester (Quartiles Q1 and Q2)
Study load	30 ECTS
Coordinator	B. Schouwstra

Characterization and Fabrication of Nanostructures (with focus on Electronics)			
Quartile 1	Quartile 2	Quartile 3	Quartile 4
<b>Characterization of Nanostructures</b> <b>201600043 (7,5 EC)</b>	<b>Fabrication of Micro- and Nanodevices</b> <b>191210730 (5 EC)</b>		
<b>Nanoscience</b> <b>193400050 (5 EC)</b>	<i>Electives: choose 10 EC</i>		
	<b>Nano-Electronics -</b> <b>193400141 (5 EC)</b>		
<i>Electives: choose 2,5 EC</i>	<b>Lab on a Chip –</b> <b>201600046 (5 EC)</b>		
<b>Optics - 202000662 (2,5 EC)</b>	<b>Quantum Optics –</b> <b>202100083 (5 EC)</b>		
<b>Molecular Structure &amp; Spectroscopy –</b> <b>202000663 (2,5 EC)</b>			

**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; Material Science; Molecular Biology; Solid State Physics; Quantum Mechanics (Quantum Physics, Level B2); Material Science; Nanoscience.

### Quartile 1

#### 201600043 Characterization of Nanostructures

This module includes a lecture part (5 EC) and an additional project part (2.5 EC).

##### Lecture Part (5 EC)

In this module, a palette of state-of-the-art characterization techniques to investigate the structure and properties of nanostructures will be introduced and applied. The module consists of 3 courses: Surface characterization (35 %), X-ray diffraction (30 %) and Microscopy and Spectroscopy (35 %). Recent publications on metal halide perovskite photovoltaics will be used as a case study to illustrate the potential and complementarity of all techniques discussed in this module.

*The modules are tentative and subject to change. Please check [the website](#) regularly. Part of this package is also possible as a 15 ECTS credits course package. Please contact your Dep. Exchange Coordinator.*

*Timetable clashes may occur.*

### *Project Part (2.5 EC)*

In this project, 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 the characterization of biological systems at the nanoscale.

### **193400050 - Nanoscience**

Fundamentals of nanoscopic physics. Introduction to Nanoelectronics (top-down vs bottom-up approach, relevant length scales). Wave/particle duality, wave functions, wave packets, and Heisenberg uncertainty relations. Free and confined electrons, free electron model, the density of states, band theory (periodic potential), tunnel junctions/resonant tunneling, single-electron tunneling. Electronic structure of quantum dots, quantum wires, and quantum wells and their transport properties. Coulomb blockade and single electron transistor.

***Electives: choose 2,5 EC***

### **202000662 – Optics**

In this part, we address the basic concepts of both geometrical optics (light as a ray) and physical optics (light as a wave). The course consists of a few lectures and a larger experimental assignment. In the lectures the theoretical concepts will be discussed, while in the experimental assignment the student will apply these concepts to design, construct and characterize an optical instrument (e.g. microscope and/or photo-spectrometer). The instrument is then used to carry out experiments that relate to the microscopic/spectroscopic characterization of materials.

### **202000663 - Molecular Structure & Spectroscopy**

This part extends the knowledge introduced in the first year quantum mechanics course and discusses the theory behind chemical bonding, as well as spectroscopic characterization. Topics being addressed involve the valence bond theory, hybridization of orbitals, molecular orbital theory, bonding and antibonding orbitals, electronic structures of molecules, an introduction to spectroscopy, with vibrational transitions, rotational transitions and electronic transitions in molecules.

## Quartile 2

### **191210730 - Fabrication of Micro- and Nanodevices**

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, and the choices of suitable techniques for the particular application/device are questioned. The important criteria (e.g. film properties, uniformity, costs, efficiency, reproducibility and 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, sensors, and micro-reactors. At the end of the course, students make short presentations about theoretically developed process flows for making a variety of structures of choice.

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## **Electives: choose 10 EC**

### **193400141 - Nano-Electronics**

Nanoelectronics comprises the study of the electronic and magnetic properties of systems with critical dimensions in the nanoregime. Quantum electronics, spin electronics, organic electronics, and neuromorphic electronics form important subfields of nanoelectronics and are being discussed in this course. Quantum electronics and neuromorphic electronics will be treated in-depth. For those who want to get a thorough introduction into the new exciting directions that will contribute to future electronics, this course is indispensable. Recommended for MSc students Nanotechnology, Applied Physics and Electrical Engineering. 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.

### **201600046 - 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 most lab-on-a-chip system is a microfluidic channel structure, through which nanoliter amounts of liquids with dissolved molecules are propelled, separated and reacted by hydraulic, electrokinetic or surface forces. The fluidic structures are machined in materials like fused silica, borofloat glass, or polymers. The course will treat a number of aspects of such microsystems in seven weeks with different themes. The students receive an introduction and assignments/a big problem on Monday and try to find solutions to the problem during the week, using a.o. the material offered in a reader. They give a presentation of their solution to the other students and the teachers on Friday, which is followed by a discussion on the subject treated. The problems offered concern the transport of liquid and dissolved molecules in microsystems, aspects of microfabrication, electrochemical and optical detection methods, the manipulation of cells in microfluidic systems and separations in microfluidic systems.

The course is aimed at MSc students of Biomedical Engineering, Electrical Engineering, Nanotechnology, Chemical Engineering, Mechanical Engineering or Applied Physics.

### **202100083 - Quantum Optics**

In this course, we study the quantum properties of light and matter-light interaction, with some examples from modern quantum technologies, such as laser cooling and trapping, Bose-Einstein condensation, and quantum sensing. After an introduction to the formalism of quantum optics, we dive into light-matter interaction. We start with the quantization of the electromagnetic field, which leads to the introduction of the photon as the quantum of light. Then, we look at various interesting quantum states of the light field and their statistical properties, including the seminal Hanbury-Brown Twiss and Hong-Ou-Mandel experiments. Next, we introduce the machinery of multi-particle quantum optics, which will be needed in the rest of the course.

In the second part, we take a look at light-matter interaction, treating the Bloch sphere, Cavity QED and the Jaynes Cummings model, with applications to atom clocks, and quantum memories.

Finally, we turn to laser cooling and trapping and Bose-Einstein condensation. Here, we encounter some of the groundbreaking experiments from the last 25 years, showing, e.g. quantum phase transitions and the condensation of gases (or light!) to a macroscopic quantum ground state.

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