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			
Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
Nanoscience **193400050** (5 EC)	**Nano-Electronics** **193400141** (5 EC)		
Transducer Science **201400427** (5 EC)	**Lab on a chip** **201600046** (5 EC)		
Molecular Structure & Spectroscopy **202000663** (2,5 EC)	**EMstatics** **191211690** (5 EC)		
Optics **202000662** (2,5 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); Basic understanding of Classical Mechanics; Nanoscience; Electro and Magneto Statistics; Electromagnetism.

Quartile 1

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.

201400427 - Transducer science

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.

In modern electronic information systems, transducers play an increasingly important role; where powerful computing, large data storage, and high bandwidth digital communication can be harnessed in ever-shrinking form-factors, transducers are indispensable in the interaction with the environment. On an individual level there seems to be an insatiable desire to know as much as possible from how much and how we move, our physical condition (blood pressure, heart rate), where we are (GPS), etc. But even more so in technical contexts transduction is at the heart of measurement & data gathering as well as locomotion, e.g. in robotics, process control, medical settings, automotive. In short: transducers (sensors and actuators) are an integral part of our modern cyber-physical systems. Examples of transducers are loudspeakers, recording-heads for magnetic data-storage, microphones, pressure sensors, electric engines, etcetera. Central to the description of transducers are the concepts of energy, ports, extensive and intensive quantities, Legendre transformation and co-energy, electrostatic-, magnetic-, piezo-electric and mechanical energy-density. Important characteristics of transducers such as energy-conversion efficiency, static and dynamic behaviour as well as stability in loaded and unloaded operation are discussed. The course examines the so-called 'energy-buffering transducer' in detail and explores how this type of transducers can beneficially be used to implement parametric effects, such as amplification, mechanical-amplitude modulation, etc. Noise is treated both with respect to its detrimental effects on sensors as well as how it can be effectively used to improve the signal to noise ratio in so-called 'Stochastic Resonance' schemes. A few short excursions to the field of bio-mimetics will be made, especially in the context of performance metrics and optimisation. In this course, some classical mechanics, network analysis and electromagnetic field theory is used and basic knowledge from other physical domains is refreshed or, if necessary, offered to the students. The course forms valuable prior knowledge for the courses EMStatics (191211690) and MEMS Design (191211300).

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.

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.

Quartile 2

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.

191211690 – EMstatics

This course focuses on computation of quasi-static electrical and magnetic fields of technical constructions (as well as systems that can be described physically in analogue fashion). Examples are capacitors, write/read transducers for magnetic recording, periodic systems like patterned recording media, EM-fields shields, particular transducers, MEMS & NEMS devices, transistors, etc.

Analytical computational methods and FEM (Finite Element Methods) will both take 50% of the time. Students will become familiar with the possibilities and (dis)advantages of both methods of approach. They will learn interpreting the FEM results and will apply the analytical methods for validating the FEM results. Some attention will be paid to the analogy of mathematical approach for different application fields such like electrical, magnetic, mechanical, diffusion and heat conduction. EMstatics is positioned between the more or less superficial approach (like for instance in freeFEM++ or Comsol), and the extensive and mathematically profound treatments in the established courses for mathematics and mechanical-engineering students.

Attention will be paid to:

1. The fundamental mathematics of static EM-field problems.
2. The choice for an analytic method or a numerical (finite element) approach.
3. Analytical and numerical computation of one- two-, and three-dimensional electromagnetic fields. Finding the most useful method of approach.
4. Validation and interpretation of the computational results.
5. Recognising analogies for computation of fields in the electromagnetic domain on the one hand, and in analogical physical domains (mechanical, heat flow, fluid mechanics) on the other.

The course will be setup with 7 assignments, which will lead to problem-based learning. These cases will be discussed with the instructors on an individual basis, or in small groups. The assessment will be based on the work on a final case. Student will apply the commercial software package “Comsol multiphysics”, using a licence which is valid during the course.