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 Chemical)			
Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
Nanoscience **193400050** (5 EC)	**Advanced Drug Delivery and Nanomedicine** **202200254** (5 EC)		
Nanophysics **193530010** (5 EC)	**Lab on a Chip** **201600046** (5 EC)		
Biophysical Techniques & Molecular Imaging **193640020** (5 EC)	**Organic Materials & Polym. Science** **193700030** (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); Bachelor Physics; Theory of Solid State Physics.

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.

193530010 - **Nanophysics**

In this course we focus on low-dimensional systems with typical length scales in the range of 1-100 nm. At this small length scale quantum mechanical phenomena play a dominant role in the physics of devices. Prominent topics are quantum electronic transport (Landauer-Büttiker formalism), coherent and incoherent transport, Coulomb blockade, and the integer quantum Hall effect. We also discuss the electronic band structure and topology of two-dimensional (2D) materials and twisted 2D (moiré) materials. We will elaborate on spin-orbit induced band inversion (the Kane-Mele model), the bulk-boundary principle, Berry phase, Berry curvature, Berry connection and Chern number for graphene and graphene-like materials. We also discuss the quantum spin Hall effect, the quantum valley Hall effect and Wigner crystallization in two-dimensional topological insulators and/or twisted bilayer graphene. The physical description of these phenomena is often illustrated by examples obtained from scientific articles.

193640020 - **Biophysical Techniques & Molecular Imaging**

Fundamentals fluorescence and vibrational transitions, related parameters; instrumentation spectroscopy and microscopy (widefield, confocal, fluorescence, Raman); fluorophores (intrinsic, extrinsic, fluorescent proteins) and labeling strategies; monitoring molecular interactions (anisotropy, MST, FCS, quenching), molecular motion (FRAP, FLIP, FCS); single-molecule spectroscopy; super-resolution microscopy (single molecule localization, STED); accessing molecular structure (fluorescence based, electron microscopy)

Quartile 2

202200254 - **Advanced Drug Delivery and Nanomedicine**

Advanced Drug Delivery and Nanomedicine (ADDN) course provides both fundamental and applied knowledge on the topic of drug delivery and nanomedicine. Conventional medicines, either administered orally or systemically, are not always sufficient for achieving the desired therapeutic effects but rather exhibit adverse 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 with low side effects can be achieved. A large part of the course will be devoted to different drug delivery systems including nanomedicine. Besides drug delivery systems, the use of nanomedicine for imaging and diagnostics as well as theragnostic (therapeutics + diagnostics), will be covered during this course. Furthermore, a genetic disorder or chronic disease can be treated by delivering nucleic acid (DNA or RNA) to the pathological cells, inducing or suppressing a specific genetic function. Also, gene delivery technologies are crucial to develop vaccines such as mRNA vaccine against COVID-19. The ideal drug or gene delivery system should be nontoxic, biocompatible, safe, simple, and easy to fabricate as well as should provide efficient targeting. This course provides an in-depth overview of drug and gene delivery technologies including nanomedicine.

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.

193700030 - Org. Materials & Polym. Science

1920-2020 – a century of polymers and organic materials! Organic materials feature enormous variations in their physical properties as a result of the tremendous wealth of the different possible existing molecular structures of carbon based compounds. The consequence of this plethora of properties is that function and use of organic materials can be tailored by controlling molecular structure virtually at will by using modern synthetic approaches, allowing one to realize many advanced applications, which belonged to the realm of phantasy just a few decades ago. In this lecture course molecular structure-property relations will be discussed for the different types of (advanced) synthetic and natural (macromolecular) organic materials, including man-made polymers, nanoparticles, degradable polymers, polymer coatings and novel processing methods, e.g. 3D printing.

The course starts with a history of polymer science and the peculiar molar mass and molar mass distributions inherent to synthetic and also certain natural polymers. The determination of molar masses is a critical factor for all organic materials and will be covered to set a basis for the coming topics. Approaches will be treated which allow materials engineers to quantitatively estimate physical properties based on the molecular structure. Effects of processing on structure (texture) and hence on properties will be demonstrated (coatings, processing techniques but also by synthetic means). A description and comparison of the major classes of the most frequently used industrial polymers for the different functions will complement this course. In addition to single-component single-phase systems, polymer blends (mixtures), block copolymers and polymer composites will also be discussed. These materials allow one to combine the useful properties of individual constituents in one system and achieve targeted improved properties. The physical principles of multicomponent phase diagrams of polymers and microphase separation in block copolymers will be treated. One particular advantage of polymers is related to their ease of processability. Processing introduces texture in the material, hence processing-structure (orientation) effects need attention. For demanding structural applications (sports, aerospace, etc...) the mechanical properties must be further enhanced. Polymer (nano)composites can combine easy processing with superior mechanical (and other improved physical) performance. Hence a section on polymer (nano)composites will also be included in the course. Major classes of advanced soft matter, e.g. in electroactive and nanomaterial applications will be elucidated. The class will end with a student mini-symposium on current interesting and relevant topics of modern soft matter and polymer science.

This is an advanced level graduate course, thus basic knowledge of organic chemistry, materials science and polymer science taught in the bachelor curriculum is a prerequisite and that knowledge will be required. The course focuses on materials and materials properties, basic knowledge on polymer chemistry is expected but we also suggest the Polymer Synthesis and the Sustainable Organic Chemistry classes as a follow-up to this course with a focus on syntheses methods.