UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Properties and Applications of Nanostructured Materials

2627-3-ESM01Q019

Aims

The scope of the course is to present fundamental physical concepts of metallic and semiconducting nanostructres and an overview of their main and more recent technological applications.

Learning Outcomes
Knowledge and understanding:
• Detailed knowledge of the basic concepts and approaches in nanostructured materials research.
• Understanding phenomena derived from quantum confinement.
• Knowledge of the main nanostructuring techniques and practical applications of nanostructured materials in various fields.

Applying knowledge and understanding:
• Acquisition of the ability to apply the notions covered in the course to the effective description of nanostructured materials.

Communication skills:
• Aquisition of written and oral communication skilles on topics related to nanostructured materials physics and chemistry.

Making judgements:
• The student will acquire the competence to judge which phenomena and observable of a given material can be ascribed to nanostructuring.

Learning skills:
• The student can extend what he has learned in the lectures to case studies not covered during the course. In particular, he can independently manage the vast literature dedicated to nanostructured materials.

Contents

The course will give basic concepts of nanostructures physics and their applications with particular attention to the dimensionality effects on the electronic and optical properties of materials.
The course will also provide basic notions on the synthesis and characterization techniques for nanostructured materials.

Detailed program

1. "Classical" distinction of nanostructured based on dimensionality (0D, 1D, 2D) - Subdivision for materials types (metals, semiconductors, etc).
2. Overview of the nanostructuring effects on the electronic, optical and dielectric properties of materials with increasing complex models from the free electron gas to the effective mass approximation.
3. Metallic nanostructures: key research objectives of the modern science of metallic nanostructures - main synthesis methods ("top-down" and "bottom-up") of metallic nanoparticles - optical properties of metallic nanoparticles, surface and localized plasmons, applications (sensors, nanomedicine, optoelectronics).
4. Semiconducting nanostructures: quantum confinement - quantum wells - quantum wires - quantum dots - with infinite and finite barriers - superlattices, main synthesis and growth methods and their thermodynamics and kinetics - electronic properties - optical properties - optoelectronic properties - applications (LED, LASER, photovoltaics).
5. Van der Waals materials and derived nanostructures: techniques to obtain atomically thin monolayers, mechanical exfoliation, liquid exfoliation. Van der Waals epitaxy, CVD. Engineering strategies for 2D materials i.e. strain and heterostructuring.

Prerequisites

Knowledge of quantum mechanics, classical electromagnetism. Basic knowledge of thermodynamics, solid state physics and chemistry.

Teaching form

The course will be structured in 24 in-person frontal lectures of two hours each (48 hours in total).
The lectures will be given in Italian.

Textbook and teaching resource

Slides will be made available to the students through the present e-learning platform.

Main textbooks:

- Quantum Wells, Wires and Dots: Theoretical and Computational Physics of Semiconductor Nanostructures, Harrison & Valavanis 2016, John Wiley & Sons, Ltd (free online with unimib credentials, https://onlinelibrary.wiley.com/doi/book/10.1002/9781118923337);

- Metal nanoparticles: synthesis, characterization, and applications, Felheim & Foss, 2002, Marcel Dekker, New York;

Semester

Second semester

Assessment method

Oral exam divided in two parts within a single exam session.
The exam will assess the general preparation of the student on the contents of the course. In particular, in the first part the student will be asked questions regarding theoretical/formal contents from which the properties of nanostructured materials derive. The second part, will assess the student's knowledge of the main nanostructures fabrication strategies, selected among those studied during the course.
There will be no ongoing assessments.

The grading scale is as follows:
< 18: insufficient grade; minimum level of preparation not achieved;
18-21: preparation covering a limited number of topics from the course syllabus; limited ability to discuss and analyze topics, often requiring prompts or questions from the instructor; presentation skills and vocabulary not always correct; limited capacity for critical analysis;
22-24: preparation covering a portion of the course syllabus; limited ability for independent analysis; use of correct - though not entirely accurate or clear - vocabulary; presentation skills that are at times uncertain;
25-27: preparation covering a wide range of topics from the course syllabus; ability to independently develop arguments and conduct critical analysis; ability to apply knowledge to concrete cases; use of correct vocabulary and competence in using discipline-specific terminology;
28-30/30L: complete and comprehensive preparation on the exam topics; ability to independently discuss and critically analyze themes; excellent capacity for critical and independent thought; full mastery of discipline-specific terminology and a rigorous, articulate presentation style.

Office hours

From Monday to Friday at any working hour (an appointment should be arranged with the teacher by email).

Sustainable Development Goals

CLEAN WATER AND SANITATION | AFFORDABLE AND CLEAN ENERGY | INDUSTRY, INNOVATION AND INFRASTRUCTURE | SUSTAINABLE CITIES AND COMMUNITIES