



UNIVERSITÀ  
DEGLI STUDI DI MILANO-BICOCCA

## COURSE SYLLABUS

### Properties and Applications of Nanostructured Materials

2526-3-ESM01Q019

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#### Aims

The scope of the course is to present fundamental physical concepts of metallic and semiconducting nanostructures 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 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:

- Acquisition of written and oral communication skills 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, dielectrical and mechanical properties of materials.
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 plasmons, applications (sensors, nanomedicine, optoelectronics).
4. Semiconducting nanostructures: quantum confinement - quantum wells - quantum wires - quantum dots - colloidal quantum dots - main synthesis and growth methods - electronic properties - optical properties - optoelectronic properties - applications (LED, LASER, photovoltaics, bioimaging).
5. Van der Waals materials and derived nanostructures: techniques to obtain atomically thin monolayers, mechanical exfoliation, liquid exfoliation. Van der Waals epitaxy, CVD. Effects of extreme nanoconfinement on electronic and mechanical properties. 2D materials applications. 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.

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 technological applications of a specific class of nanostructures, selected among those studied during the course.

There will be no ongoing assessments.

## **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

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