



UNIVERSITÀ  
DEGLI STUDI DI MILANO-BICOCCA

## SYLLABUS DEL CORSO

### Nanotechnology and Innovation

2223-2-F5302Q006

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#### Aims

The aim of the course is to provide in depth knowledge on various classes of nanomaterials that will constitute the main ingredient of future nanotechnologies. For each materials class, the synthesis approaches and the physical mechanisms underpinning their functionality will be studied in detail with particular focus on size-related processes, such as quantum and dielectric confinement.

Applications of nanomaterials in various technological fields will be considered and their functioning principles will be studied, highlighting promising strategies for their design and optimization.

Regulation aspects regarding health, safety and environmental aspects of nanotechnology will be discussed.

#### Contents

The following classes of nanomaterials will be discussed:

1. Metal clusters: Bottom-up and top-down synthesis approaches, surface functionalization, electronic structure and size effects. Optical properties and photophysical processes. Application in optoelectronic devices, sensors and biologic imaging.
2. Plasmonic metal nanoparticles: basic principles of plasmonics in dielectric confined nanomaterials, dielectric confinement, plasmon resonance and size/environment effects. Optical properties vs. size and dimensionality. Hot carriers in nanomaterials. Plasmon enhanced Raman spectroscopy. Plasmon enhanced fluorescence. Coulomb blockade effect and the concept of charge quantization. Applications in phototherapy and sensing.
3. Colloidal semiconductor nanocrystals: Synthesis and surface chemistry, density of states in 3D and in 2D dimensional systems, electronic properties, excitonic (fine) structure, size and shape effects. Heterostructures and wave function engineering. Detailed photophysics, Electric transport. Doping and magnetic properties. Applications

in LASERS, LEDs, bioimaging and energy technologies.

## **Detailed program**

### 0. Introduction to Nanotechnology:

- History
- Health and safety aspects
- Regulations on nanomaterials

### 1. Metal Clusters:

- Synthesis approaches (top-down and bottom-up)
- Surface functionalization
- Electronic structure and size effects
- Photophysics and optical properties
- Optoelectronic devices, sensors and biomarkers based on metal clusters.

### 2. Plasmonic Nanoparticles

- Basic principles of plasmonics in low-dimensional systems
- Dielectric confinement
- Plasmonic resonance vs. size and environment
- Coulomb blockade
- Applications in thermo-therapy and sensing

### 3. Colloidal Semiconductor Nanocrystals

- Colloidal synthesis, mechanisms
- Surface chemistry
- Electronic confinement and density of states in semiconductor nanostructures
- Electronic properties and exciton structure
- Size effects on the electronic properties
- Heterostructures: design criteria and synthesis approaches
- Wavefunction engineering

- Doping
- Photophysics and magnetic properties
- Application in LASERS, LEDs, bioimaging and renewable energy technologies.

## **Prerequisites**

Basic chemistry and chemical physics. Quantum mechanics, solid state physics.

## **Teaching form**

Classroom lectures

## **Textbook and teaching resource**

Books suggested by the lecturer, slides and review articles.

## **Semester**

Second semester

## **Assessment method**

Presentation by the candidate (20-25 minutes) on a subject of choice pertinent to the course and oral discussion.

## **Office hours**

To be agreed with the professor.

## **Sustainable Development Goals**

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

