UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Chimica per le Nanotecnologie

2021-2-F5401Q057

Aims

The student must acquire the theoretical, conceptual and methodological fundaments on preparation, characterization and applications of the inorganic and organic matter at the nanometric scale. The course includes a module more oriented to the applications in the field of chemistry and materials science, and a module more oriented to the biomedical and biotechnological field

Checking knowledge and understanding

At the end of the course the student knows:

- fundamental principles that determine the behavior of matter at the nanoscopic scale;

- methods for preparing nanoparticles, nanostructures, nanofilms, nanopolymers, biopolymers, etc;

- methods for characterizing nanodimensional systems, both with spectroscopic and microscopics methods;

- applications of nanomaterials in the fields of energy, electronics, automotive, applications to the textile industry, sensors, decontamination, etc.

- nanoparticles for therapeutic and diagnostic applications. Biological problems that must be faced:

fundamental principles of the immune system, biological barriers and corona proteins, organs and tissues features.

- strategies to control drug delivery, how to target nanoparticles to specific issues and organs. Molecular recognition.

- methods for functionalization of nanoparticles with drugs, diagnostics and targeting molecules. Chemoselective conjugation methods.

- applications of nanomaterials in the fields of diagnostics, therapeutics, tissue engineering, biotechnologies, and life sciences.

- main applicationa of nanoparticles in biomedicine.

- nature, production and applications of nanostructured biomaterials mimicking tissues and organs.

Knowledge and understanding skills applied

At the end of the course the student will be able to:

- Recognize the added value of the nanostructured materials, the importance of supramolecular chemistry for the creation of new aggregates with specific functions, choose the most suitable characterization techniques, identify the application fields of the substances prepared at the nanometric scale;

- Evaluate the applicability of polymers of different nature for biomedical purposes; choose the appropriate synthetic methodologies useful for the development of nanosystems (nanoparticles or biomaterials) for diagnostic and / or therapeutic purposes, identify the most suitable formulation methodologies based on the target biological system.

Autonomy of judgment

At the end of the course the student is able to:

- Recognize the potential of a given nanotechnology for immediate practical applications in the chemical, microelectronic and manufacturing industries;

- The innovative potential of research in the bio-nanotechnology field and in the biomedical field;

- The potential long-term effects of nanoscience and nanotechnology.

Communication skills

- At the end of the course the student has learned how to describe in a technical report the main advances in a given sector and to clearly and synthetically explain the objectives, the procedure and the results of the elaborations carried out with language properties.

Ability to learn

Being able to apply the acquired knowledge to contexts different from those presented during the course, and to understand the topics covered in the scientific literature concerning the chemical aspects of nanotechnology.

Contents

1st Module. Nanomaterials for catalysis and photocatalysis. Historycal introduction: birth and definition of nanotechnologies. Catalysis: the oldest nanotechnology. Catalysis by supported particles. Catalyst characterization (TEM, STM, AFM, XPS). Nature of the support: defects; surface sites, surface reactivity. Nanoporous materials.

Nanotechnologies for energy and environment. Photocatalysis; self-cleaning; conversion of solar light into energy.

2nd Module. Nanoparticles for therapeutic and diagnostic use, nature, functionalization and applications. Nanostructured biomaterials for regenerative nmedicine, nature, properties, functions and applications.

Detailed program

1st Module. Nanomaterials for catalysis and photocatalysis. Historycal introduction: birth and definition of nanotechnologies. From clusters to nanoparticles, to colloids: evolution of properties of matter with size; clusters: aggregates with non scalable properties (quantum size); nanoparticles: aggregates with scalable properties, large surface area; colloids: synthesis, stabilization, optical properties; collective excitations (plasmons). Catalysis: the oldest nanotechnology. Catalysis by supported particles: definition of catalysis; environmental and industrial catalysis; role of nanostructuring (e.g. gold in catalysis, single atom catalysts); factors affecting the activity of a nanocatalyst; Model systems; catalyst preparation: size control (wet chemistry, nanolithography, self-assembly, mass selected particles, etc.); catalyst characterization (TEM, STM, AFM, XPS); chemical-physical properties; chemical reactivity. Nature of the support: atomistic control; oxide surfaces and their morphology; surface composition and defects; identification of surface sites for anchoring of nanoparticles; examples of surface reactivity (case study: CO on MgO). Support nanostructures: reducing dimensionality of the support: two dimensional films; nanoparticles, nanotubes, nanofilms (carbons, sulphides, oxides); controlling charge and electronic structure of supported catalyst. Nanoporous materials: materials for gas-storage and sequestration; zeolites and other nanoporous structures; metal-organic frameworks

Nanotechnologies for energy and environment. Photocatalysis by nanoparticles: semiconducting oxides; oxide nanoparticles for self-cleaning; oxide nanoparticles in conversion of solar light into energy; problem of harvesting visible part of solar spectrum; doping, nanostructuring, heterojunctions; recombination processes, efficiency; qpplications of oxide nanoparticles in various environments.

Risks associated to the use of nanoparticles. Risks and benefits. Nanotoxicology, citotoxicity

2nd Module. Recent advances in Nanomaterials for Drug Delivery and Regenerative Medicine. Nature and size of nanoparticles. Pharmacokinetics of the nanoparticles, obstacles to overcome and solutions: immune system and biological barriers. Protein corona. Strategies to generate stealth nanoparticles and to overcome the biological barriers. Strategies for controlled drug release. Strategies for targeting, receptors and ligands. Ligand-decorated nanoparticles, chemoselective approaches of conjugation. Nanoparticles for diagnostic purposes.

Nanostructured Biomaterials for regenerative medicine. The nature of biomaterials: synthetic polymeric materials; natural polymeric materials; hybrid and composite materials; self-assembled peptide amphiphile (PA) based-materials; carbon nanotube. Biomaterials functionalization strategies; biomolecules and receptors for smart biomaterials; functionalization of biomaterials with extracellular matrix proteins, with peptide sequences, with carbohydrates. Applications to personalized medicine.

Prerequisites

Basic knowledge of molecular chemistry, solid state physics, and spectroscopy.

Teaching form

Classroom lectures with preparation and discussion of a scientific report

Textbook and teaching resource

Suggested reading: *http://www.docbrown.info/page03/nanochem02.htm*

Slides of presentations

Semester

First semester

Assessment method

The exam can be taken at the choice of the student in Italian or English and consists of two tests.

The first test consists of an oral presentation, in front of the whole group of students, of a selected topic among those proposed concerning the use of nanotechnologies in the field of sustainable energy production, new innovative materials, telecommunications systems and quantum computing, sensorial and environmental applications, etc.

The second test consists of an oral presentation, with the same characteristics as the previous one, on topics related to nanoparticles for diagnostic and therapeutic use, biomaterials for tissue engineering applications, biomaterials for prothesis and biomaterials for the development of advanced in vitro cell models.

Individual oral presentations are the subject of open discussion, with questions and contradictions, and the level of knowledge acquired, the autonomy of analysis and judgment, the student's presentation skills, the ability to identify particularly promising advances in a given nanotechnology sector will be checked.

The final grade, expressed in thirtieths with possible “laude”, is the average of the grades two tests.

Office hours

Any working day by appointment and availability of the teacher.