UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Engineered Nanomaterials

2526-2-FSM01Q026

Aims

Aim of the course is to develop a fundamental understanding of the key aspect of nanomaterials, from their properties to engineering. Starting from Feynmann's vision, dating back 1959, and his famous statement "There's plenty of room at the bottom", the course will focus on the relevance of investigating and using nanomaterials in the 21th century. By combining fundamental insights on nanomaterials physics and chemistry (Knowledge and Understanding), the course will lead to design rules for engineering advanced functional materials with novel properties, to develop innovative strategies and devices (Ability to apply knowledge and understanding.). The course will focus on micro/nanoscale artificial materials, as well as natural and nature-inspired materials, with a particular focus on smart materials with special wettability. At the end of the course, the student will be able to understand complexity of nanomaterials, with critical view of both potential benefits and difficulties related to engineering implementation (Learning, self-assessment and self-regulation skills). Through a series of guided activities, inspired by the principle of flipped-classroom, the student will develop dissemination, communication and valorization skills of research activity (Communication and argumentative skills).

Contents

The course covers the basic principles associated with nanoscience and nanotechnology which is necessary to understand the nanomaterials properties, and how nanomaterials can be designed and engineered. The course will span from nanotools (characterizations and fabrication methods), to physics (size dependent properties and phenomena) and chemistry (synthesis and modification), as well as applications of materials at nanometer length scales with an emphasis on recent technological breakthroughs in the field.

Detailed program

- Overview of Nanomaterials and Nanotechnology, with historical perspective: top-down vs bottom-up approach
- Surface energy and capillary effects, down to the micro and nanoscale
- Non-wetting surfaces
- Nucleation theory: Homogeneous and heterogeneous nucleation
- Class presentations by students (after introduction by the teacher) on state-of-the-art research topics on nanomaterials, including:

1. Carbon-based nanomaterials (graphene – carbon nanotubes)
2. Aerogels
3. Ice templating of colloids
4. Nanomaterials for electrochemical water splitting
5. Biopolymer-based (e.g. cellulose) nanomaterials
6. Gecko glue and biomimethic adhesives
7. Biomineralization
8. High absorption nanomaterials (e.g. ultra-black)
9. Nanomaterials in biomedical applications

- Societal Implications: ethics, safety, environment, and public perception

Prerequisites

Teaching form

Lectures and excercises will be in the class.
Lectures and exercises are designed based on the "flipped classroom" principle, with students having an active role in a variety of activities (presentations, crowdfunding videos and research highlights), which constitute a backbone of the course and of the assessment.

Textbook and teaching resource

Primary references:

- Gabor L. Hornyak, Joydeep Dutta, H.F. Tibbals, Anil Rao, Introduction to Nanoscience, CRC Press. Published May 15, 2008. 856 Pages, ISBN: 9781420048056
- Gabor L. Hornyak, John J. Moore, H.F. Tibbals, Joydeep Dutta, Fundamentals of Nanotechnology, CRC Press. Published December 22, 2008. 786 Pages. ISBN 9781420048032
- Guozhong Cao and Ying Wang, Nanostructures & Nanomaterials: Synthesis, Properties & Applications, World Scientific (2011), ISBN 13: ISBN: 978-981-4322-50-8 (hardcover) 978-981-4324-55-7 (softcover).
- H.-J. Butt, M. Kappl. Surface and Interfacial Forces. Wiley, 2018, ISBN: 978-3-527-80436-8

Additional references:

- Sulabha K. Kulkarni. Nanotechnology: Principles and Practices. Springer International Publishing, 2015. DOI: 10.1007/978-3-319-09171-6.
- R. Kelsall, I. Hamley, M. Geoghegan. Nanoscale: Science and Technology. Wiley, 2005. ISBN: 978-0-470-85086-2.
- Michael Köhler and Wolfgang Fritzsche, Nanotechnology: An Introduction to Nanostructuring Techniques,

Second Edition, Wiley, 3 December 2007, Print ISBN:9783527318711, Online ISBN:9783527621132 DOI:10.1002/9783527621132.
- Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2nd Edition, Wiley, 1 July 2013, 386 Pages, ISBN: 978-3-527-67186.
- Gerrard Eddy and Jai Poinern, A Laboratory Course in Nanoscience and Nanotechnology, 1st Edition, CRC Press, December 6, 2014, 260 Pages. ISBN 9781482231038.

Semester

Second year, First semester (Fall).

Assessment method

The teacher assesses if and to what extent the student has reached the course objectives.
A formal knowledge-based evaluation of the general topics delivered. The examination is performed through an oral exam.

During the course, the students will also conduct a class presentation, prepare a short video anfd write a research highlight on one of the above listed topic.

The final evaluation will assess the following points:

Knowledge and Understanding. The student demonstrates mastery of the complex scientific and technical concepts, articulating connections and providing exhaustive explanations, based on scientific literature.

Ability to apply knowledge and understanding. The student demonstrates an advanced ability to analyze a phenomenon, a syhnthesis or a charatcterization method, understanding strenghts and limitations. Knowledge applications is methodologically rigorous, and supported by data and arguments.

Communication and argumentative skills. In the activities and in the final oral exam, the student presents or answers questions in clear and structured manner. The speech is fluid.

Learning, self-assessment and self-regulation skills. The student demonstrates an advanced ability to self-reflect, developing a detailed and in-depth analysis of his/her own learning and professional development path (e.g. reporting the steps in the use of generative AI during activities).

The final evaluation will be a sum of the different parts:

- Presentation: max 12 points
- Crowdfunding video simulation: max 6 points
- Research highlight: max 4 points
- Oral exam: max 8 points
- TOTAL: max 30 points

Office hours

Appointment, upon e-mail request.

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY