NANOCHEMISTRY COURSE

B TYPE @ IIT – YEAR 2020

Each 7 hours = 1 CFU

Modulo 1. Nanomaterials and Nano Heterostructures: Colloidal Synthesis and Chemical Transformations. 7 hours – 1 credit
Speaker: Luca De Trizio

The course aims at outlining the fundamental steps which characterize the colloidal synthesis of nanocrystals. In details, I will first describe the kinetics and the thermodynamics of the nucleation and growth of nanocrystals and how to control them. At the same time, the course will deal with the surface energy of the nanocrystals, which ultimately determines their shape.

Eventually, I will describe one of the most studied post-synthesis strategies that are currently employed in order to finely “modify” colloidal nanocrystals: the cation exchange reaction. This chemical tool allows for exchanging the cations of pre-formed nanocrystals with new desired cations, while retaining the original anion framework. Thanks to this technique, it is possible either to completely change the composition of colloidal nanocrystals, accessing new nanomaterials, or to engineer them, by partial cation exchange, producing alloyed or heterostructured nanoparticles.

Sala Dulbecco, martedì 28/01/2020, 10:00-12:00
Sala Montalcini, martedì 04/02/2020, 10:00-12:00
Sala Hack, martedì 11/02/2020, 10:00-12:00

Modulo 2. Transmission electron microscopy: basics and applications to materials science and life science. 11 hours – 1.6 credits
Speakers: R. Brescia, J. Buha R., Marotta, D. Debellis

Introduction to TEM: conventional imaging, electron diffraction and analytical TEM techniques
High-resolution TEM imaging and in-situ TEM in materials science
Introduction to electron microscopy in biology, cryo electron microscopy (CryoEM) and electron tomography

Introduction to TEM: R. Brescia Sala Montalcini, 18/02/2020, 10:00-12:30
High-resolution TEM imaging and in-situ TEM in materials science J. Buha Sala Montalcini, 25/02/2020, 10:00-13:00
Introduction to electron microscopy in biology, cryo electron microscopy (CryoEM) and electron tomography R. Marotta, D. Debellis Sala Montalcini, 03/03/2020, 10:00-12:30
Final test Sala Montalcini, 10/03/2020, 10:00-13:00

Modulo 3. Materials Characterization (theory and lab). 14 hours – 2 credits
Speakers: M. Prato, L. Pasquale, S. Dante, L. Ceseracciu, M. Salerno

Materials characterization will have a relevant role in your PhD path, if you are dealing with development, optimization and applications of new materials. Within this module, we will give you an overview of the characterization techniques available at the Materials Characterization Facility, through a combination of theory classes, examples and laboratory experiences. In particular, the course will deal with:

- X-ray based techniques – 10 hours: The theoretical basis as well as the practical application of X-ray Photoelectron Spectroscopy (XPS) and X-ray Diffraction (XRD) techniques will be presented, along with micro-X-
The course will also include lectures on X-ray techniques for the analysis of thin films and interfaces (X-ray reflectivity, XRR) and for the characterization of non-crystalline or partially ordered materials (small-angle scattering, SAXS). An overview of the advanced instrumentation available at the large-scale facilities for synchrotron and neutron radiation will be given.

- **Mechanical Characterizations – 2 hours**: The course will cover the basic theory of deformation of different classes of materials and their relationship with microstructure. The most common characterization techniques will be presented from both a theoretical and practical point of view, with a special focus on uniaxial tension tests. The students will be guided through the optimized selection of testing parameters as a function of the materials and of the target information investigated.

- **Atomic Force Microscopy (AFM) – 2 hours**: The lecture will present the basic principles underlying AFM operation, and will shortly comment on the meaning of roughness for 3D surface images obtained by whatever imaging technique. Examples of images will be shown, not only of topography but also of different physical quantities that can be probed on the sample surfaces (e.g. stiffness, friction, electrical potential, surface current). The experience in the laboratory will demonstrate acquisition of 3D surface morphology of common material surfaces (silicon calibration grating, glass slide or polymer surface) and basic image processing and analysis.

Sala Montalcini, mercoledì 18 marzo 2020, 10:00-12:00
Sala Montalcini, mercoledì 25 marzo 2020, 10:00-12:00
Sala Montalcini, martedì 31 marzo 2020, 10:00-12:00
Sala Montalcini, martedì 7 aprile 2020, 10:00-12:00

### Modulo 4. Introduction to polymer physical chemistry and characterisation techniques. 8 hours – 1.1 credits
**Speaker: Nicola Tirelli**

A: the concept of molecular weight distribution and what this entails, as opposed to well-defined, single-valued molecular weight.
B: macromolecules in 3D and in solution; random walk and why longer does not necessarily mean bigger.
C: characterisation techniques; why we care about viscosity and why in Gel Permeation Chromatography we just care about entropy.
D: wrap-up and assessment.

Sala Montalcini, giovedì 16/04/2020, 10:00-12:00
Sala Montalcini, lunedì 20/04/2020, 10:00-12:00
Sala Montalcini, martedì 21/04/2020, 10:00-12:00
Sala Montalcini, martedì 28/04/2020, 10:00-12:00

### Modulo 5. Theory of crystalline solids. 21 hours – 3 credits
**Speaker: Sergey Artyukhin**

The course will discuss how elastic, optical, magnetic and transport properties emerge in crystalline solids. Particular attention will be given to crystal field theory, bonding, symmetries, phonons, Jahn-Teller effect, physics of transition metal ions, optical properties, collective phenomena, such as ferroelectricity and magnetism.

Sala Montalcini, giovedì 02/04/2020, 11:00-13.00
Sala Montalcini, venerdì 17/04/2020, 11:00-13.00
Sala Montalcini, mercoledì 22/04/2020, 11:00-13.00
Sala Montalcini, mercoledì 29/04/2020, 11:00-13.00
Sala Hack, venerdì 8 maggio 2020, 10:00-12:00
Sala Hack, martedì 12 maggio 2020, 10:00-12:00
Sala Hack, giovedì 14 maggio 2020, 10:00-12:00
Sala Hack, lunedì 18 maggio 2020, 11:00-13:00
Sala Hack, venerdì 22 maggio 2020, 10:00-12:00
Sala Montalcini, lunedì 25 maggio 2020, 14:30-16:30

### Modulo 6. Optoelectronics of Nanomaterials. 14 hours theory and lab – 2 credits
**Speakers: Ilka Kriegel, Dmitry Baranov, Francesco Di Stasio**
Dmitry will do the practical part on experimental techniques of measuring absorbance and photoluminescence spectra of nanomaterials in solid and liquid forms (will be conducted in the lab). 4 hours

Ilka will cover the fundamentals of optical properties with examples from the literature. 6 hours

Francesco will focus on applications such as nanomaterial-based semiconductor junctions, light-emitting diodes, lasers and single-photon emitters. 4 hours

Sala, Montalcini, martedì 26/05/2020, 10:00-12:00
The others will be booked (early/mid June)

**Module 7. Atomic Force Microscopy, theory and practice. 14 hours – 2 credits**  
*Speaker: Marco Salerno*

Using force for probing materials properties with high spatial resolution.

Atomic force microscopy (AFM) is the major technique of the scanning probe microscopy family born in the last 20 years of the past century. In AFM in particular the interaction force between probe tip and sample is used as a mechanism for detection and local mapping of the sample material properties. The course will unveil the principles and mechanisms of AFM operation as a force sensor, in the different configurations of static (contact mode) and dynamic interaction (tapping mode). In particular for the latter, the interpretation of the behavior of the observables, namely amplitude and phase of the cantilever oscillation, will be carried out in detail.

The analysis of AFM operation will be done with both analytical means based on the theory of the damped, forced simple harmonic oscillator, as well as with computer simulation based on the freeware online program VEDA. Examples of real imaging and related issues on diverse materials (semiconductors, organics, composites etc) will be presented and discussed.

The course will include practice on the different AFM systems available at iit, as well as homework and exam tests for verification of learning of the main concepts involved.

June-July

**Module 8. Introduction to Nanobiosensors / Nanostructured materials for biosensors. 7 hours – 1 credit**  
*Speaker: Marco Salerno*

- Measuring system, sensors and technology, sensitivity / LOD, filtering
- possible sensors classifications: biosensors, chemical sensors; why nanosensors
- types of bioanalytes: biomolecules, biopolymers, viruses/bacteria
- random walk, diffusion distance, sensor surface “stickyness”, labeled biosensors
- label-free biosensors: amperometric, potentiometric, cantilever based
- geometric sensitivity gain: electrostatics analogs
- planar sensor, nanowire sensor, fractal surface sensor: regular and irregular fractals
- settling time and fundamental LOD, capacitance analog to sensors
- sensitivity and transducer-specific LOD
- selectivity and practical LOD
- a full table sensors; strategies to beat the diffusion limit

September

**Module 9. Water soluble nanoparticles. 7 hours – 1 credit**  
*Speaker: Teresa Pellegrino*

- Water transfer protocols of inorganic nanoparticles
- An overview of characterization techniques of water soluble nanoparticles
- Cytotoxicity of nanoparticles: methods to evaluate cytotoxicity
- Fate of nanoparticles: biological transformations of inorganic nanoparticles into living cells

October