Scuola Superiore di Catania

Classe delle Scienze Sperimentali
Corso specialistico
Ambito Scienze e Tecnologie

"Nano-bio-hybrid interfaces for applications in energetics"
"Nano-bio-interfacce ibride per applicazioni in energetica"

a.a.2015-2016

The course addresses the fundamental question of what BIO may do with NANO, from the point of view of improving chemical, electrical, optical and thermal properties of materials for energy applications. Specifically, the course aims to provide an overall picture of the energy systems, current and future challenges in energetics, nano-bio hybrid materials designed for effective use in energy-related devices. State-of-the art systems, fabrication strategies as well as the understanding and control of the interfacial reactions and phase transformations in these devices will be elucidated. The course is structured in three coherent modules, described as follows.

Module 1. **Bio-nano hybrid materials for energy applications**
Physicochemical aspects of hybrid biointerfaces for two different fronts of:

- nanofabrication of photovoltaic, thermoelectric, and nanoelectronic materials by biomolecule-guided self-assembly;
- biomolecule-driven evolution of inorganic catalysts for energy applications.

Case studies treated for the controlled self-assembling processes and/or enhancement of the material properties include:

- bionanoassembly that makes use of biological inspiration and biomacromolecules for fabrication of specific nanostructures via molecular recognition (for instance, programmable assembly using DNA tile building blocks and viral particles for the assembly of a variety of nanoscale materials into complex structures).
- Peptide nanotubes, formed by self-assembly of aromatic peptides building blocks, with unique second harmonic generation, piezoelectric and ferroelectric polarization, electrochemical properties.

Biomaterials used as electrode materials in rechargeable lithium batteries, in solar and fuel cells will be discussed. Specific aspects considered for the integrated biomolecule-inorganic materials systems are:

- the role of biomolecule-nanoparticle coupling strategies and the fabrication methods in the improvement and modification of the characteristics of the bio-nano hybrid material (e.g.,. in protein-based photonic devices of bacteriorhodopsin coupled to quantum dots, the increased efficiency of light collection by resonant energy transfer, FRET).
- The structures and operation modes of bioengineered nanostructures for enhanced photovoltaics and artificial photosynthesis.
- Energy-harvesting and energy-storage devices based on soft materials that mimick living tissue.

Module 2. **Materials and devices for harvesting, transport, storage, conversion and utilization of energy.**
This module will cover aspects from material synthesis and characterization to the integration of these materials into devices.
Specifically, basics concepts of chemical, physical and material engineering of various systems of interest for energy applications will be treated. The materials classes considered include:

- nanocarbons;
- thin films and semiconductors;
- electrocatalysts;
- membranes and membrane-electrode assemblies.

The integration of such materials into devices for energy applications will be elucidated for the

case studies of:

- batteries and supercapacitors;
- photovoltaic cells;
- solar cells;
- electrochemical cells for energy storage.
- (bio)fuel cells.

Module 3. **Catalysis, nanotechnology and biomimetics for energy.**
This module will cover fundamental and applied concepts of surface and interfaces in catalysis, nanotechnology and biomimetics for energy systems. Topics addressed include:

- a general intro to heterogeneous catalysis – adsorption, desorption, reaction on catalyst surfaces, reaction mechanisms and kinetics;
- specific catalysis of energy relevance; petrochemical, fuels, conversion, catalysis for energy efficiency in industrial processes,…;
- environmental catalysis in energy related systems (catalytic converters in the transport sector,….);
- A time-based standpoint about nanoscience and nanotechnology for energy and environment applications, the past (gross features), today and some future prospects (IEA scenarios etc). Specific examples will also cover systems aspects – like the demands for smart grids, the barriers to electrical or hydrogen vehicles due to limited distribution systems etc.
- hydrogen storage;
- photocatalysis for fuel production with sun light (hydrogen production, CO_2 conversion to fuels, …;
- artificial photosynthesis;
- enzymatic biofuels.