1) Development of colloidal nanocrystals for energy related applications

Tutor IIT: Liberato Manna, Luca De Trizio
3 phd scholarship

The need to reduce the pollution connected with the combustion of petrol and carbon is increasingly pushing research toward the development of new materials that can be used in energy conversion devices and/or that can decrease the energy demand of devices (e.g. for telecommunications or light emitters). Solar cells or solar concentrators, for instance, enable the direct conversion of the solar energy into electrical power, thus generating “green” energy. Colloidal semiconductor nanocrystals (NCs) have been shown to be promising materials for low-cost and high efficiency solar cells, solar concentrators and light emitting optoelectronic devices thanks to their unique properties and to the low costs associated with their synthesis. For example NCs having a stokes-shifted photoluminescence (PL) emission can be optimal candidates to be employed in plastic-based solar concentrators or even for scintillators. The latter are devices capable of detecting ionizing radiation which could be potentially employed for (clean) energy production (in particular in future fusion reactors) as well as for strategic technologies including homeland security, medical diagnostics and environmental monitoring. On the other hand, NCs emitting in the near infrared could be exploited in solar cells and/or low-cost near infrared based optoelectronic devices (e.g. night vision, optical telecommunications, food quality assessment ecc).

In general, the optical properties of colloidal NCs can be finely tuned to match the required standards, and the NCs, in the form of inks (i.e. dispersion of NCs in a desired solvent) can be readily employed in low cost ink-jet processes for the fabrication of devices. This research activity will be first focused on the synthesis of nanocrystals (targeting for example emerging metal halides, metal oxides, metal chalcogenides and pnictides) and heterostructures (i.e. nanocrystals composed of two (or more) domains of different materials). Doping/alloying strategies will be also pursued in order finely tune the optical properties of the above-mentioned nanostructures. The nanocrystalline products will be subjected then to a complete (structural, chemical, surface and optical) characterization. Both the nanocrystals and the heterostructures will be engineered in order to optimize their optical and/or electrical properties.

Requirements: The ideal candidate must have a Master Degree in one of the following areas: Material Science, Chemistry, Chemical Engineering or Physics.
For further details concerning the research theme, please contact: liberato.manna@iit.it, luca.detrizio@iit.it

2) Synthesis and characterization of organic materials based on Sulfur (II)-containing polymers, and their biological anti-oxidant performance*).

Tutor IIT Nicola Tirelli

Sulfur (II) organic polymers (polysulfides, polythioacetals) can effectively scavenge biologically relevant oxidants (Reactive Oxygen Species, ROS) such as hydrogen peroxide or superoxide. Since ROS typically act as inflammatory mediators (both intra- and inter-cellularly), their removal has important anti-inflammatory consequences [1,2]. Further, ROS-scavenging polymers may also fulfil a protective (sacrificial) role for sensitive molecules such as therapeutic proteins, being oxidized in their stead [3]. This project aims to develop hydrophilic ROS-scavenging polymers, such as poly(thioglycidyl glycerol). The objective is to employ them as functional components of systems (nanoparticles), which are designed to intracellularly deliver nucleic acids.
The skills developed in the project will include monomer/polymer synthesis (including microfluidic-assisted scaled-up processes), nanomaterial/colloidal characterization, culture and molecular biology characterization of mammalian cell lines. Previous experiences in polymer synthesis are strongly preferred.


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**3) Development and preparation of colloidal nanocrystals with chiroptical activity**

Funding: project TWISTEDNANO

Supervisor IIT: Francesco Di Stasio

Co-supervisor UNICE: Paola Lova

The quest for new medical drugs demands reliable, ultrasensitive and fast techniques to identify, refine and test small volumes of molecules for clinical trials. The efficacy of pharmaceuticals depends to a large extent on their chiral composition, and thus enantiomeric purity and selectivity is an important issue for the development of new drugs and to test their biotoxicity. Project TwistedNano (EIC-Pathfinder OPEN 2021) addresses this need with a new generation of integrated nanophotonic devices enabling ultrasensitive chiroptical spectroscopy of sub-nanolitre volumes, revolutionizing at-source the sensing technological toolbox for drug discovery and nanomedicine.

The project aims at developing a photonics-enabled chiral sensing technology that integrates vectorial structured light fields with almost arbitrary control onto a microfluidic chip, providing groundbreaking advantages compared to current instrumentation: (i) remote/distributed analysis, (ii) reduced sample consumption, (iii) cost reduction, (iv) parallelization, (v) increased diagnostic speed and sensitivity.

At IIT, the PhD candidate will focus on the development of photonic nanostructures via colloidal chemistry. In view of this, the activities will focus on chemical synthesis, together with extensive optical characterization (steady-state and time-resolved). Importantly, the PhD candidate will develop synthesis protocols leading to chiroptical active colloidal nanostructures based on noble metals, transparent conductors, and/or colloidal semiconductors. Such nanostructures will then be exploited by other consortium members (in the framework of project TWISTEDNANO) in combination with miniaturized twisted photonic platforms for efficient radiation confinement and programmable super-chiral field design.

Within the research team, your main responsibilities will be:

- Colloidal synthesis of nanoparticles.
- Manipulation and characterization of nanomaterials. Comprehensive investigation of their structural and morphological properties.
- Fabrication and characterization of nanophotonic architectures, with the specific aim of realizing strongly coupled hybridization between chiral light and semiconductor nanocrystals.
Requirements: The candidate should have a master’s degree in material science, chemistry or related disciplines, with possibly some experience in colloidal chemistry. Importantly, candidates should be driven by strong work dedication and experience in working in an international environment will be positively considered.

Funding for this position is provided by European Innovation Council through the project Pathfinder OPEN 2021 “TWISTEDNANO”, for more information please visit: https://www.twistednano-horizon.eu/. For questions concerning the research theme, please contact Francesco.DiStasio@iit.it.

4) Physically chemical interactions of magnetic based nanomaterials with immune cells"
Funding: project ERC consolidator GIULIa (PI Teresa Pellegrino)
Supervisor IIT: Teresa Pellegrino
Co-supervisor UNIGE: Davide Peddis

Magnetic hyperthermia (MHT) is a new therapeutic approach that enables to ‘burn’ tumor cells by means of the heat generated by magnetic nanoparticles under time varying fields. Different clinical trials are now ongoing to treat different types of solid tumors. In GIULIa project, we will apply MHT for the treatment of metastasized tumors. MHT treatment of cancer metastases is now not doable because of scarce MNP dose accumulation at the spreading tumor sites. In GIULIa, MNPs designed for MHT, will be loaded in/on immune cells, which will work as Trojan horses to deliver the right dose of magnetic materials needed for mild or hot MHT to the metastases.

The project aims at developing strategies to maximize the association or uptake of magnetic based nanomaterials to immune cells while maintaining intact the functionality of immune cells at no cell toxicity, providing ground-breaking advantages including (i) infusion of the minimal dose of immune cells at the highest dose of magnetic nanoparticles; (ii) reduced magnetic material consumption, (iii) fast loading process at the minimal cost reduction, (iv) safe conditions, (v) providing enough dose of magnetic materials for magnetic hyperthermia; (vi) track and quantify magnetic nanoparticles by magnetic particle imaging (MPI) and magnetic resonance imaging (MRI) in phantoms.

At IIT, the PhD candidate will focus on the development of different functionalization coating of magnetic based nanomaterials via different wet colloidal approaches. Among them, the candidate will learn and apply polymer preparation and polymer functionalization with different moieties, polymer coating and lipid coating, ligand exchange procedures and inorganic silica growth methods of magnetic based nanomaterials. An important part of the study will be dedicated to correlates the physical and chemical parameters of the nanomaterials, including magnetic properties, shape, size, assembly structure, surface charge to the uptake or association to/on immune cells in terms of materials uptake, preservation of cell functions and survival, magnetic properties of interest in particular magnetic hyperthermia heating performance, MPI and MRI signaling, magnetic manipulation under different magnetic stimulation.

The PhD candidate will also develop loading protocols which will lead to scalable and reproducible processes and they will be possibly implemented to different types of immune cells.

Within the research team, the candidate main responsibilities will be:

- Preparation of water soluble magnetic nanomaterials,
- Magnetic, physical and chemical characterization of nanomaterials.
- Magnetic, physical and chemical characterization of immune cells loaded with magnetic based nanomaterials
- Full investigation of structural and morphological features of immune cells loaded with magnetic materials.
• Full investigation of MPI, MRI, magnetic accumulation studies and magnetic hyperthermia study of immune cells loaded with magnetic materials.
• Deep investigation of the functional and molecular profiling of immune cells treated with magnetic based materials.

Requirements: The ideal candidate should have a master’s degree in biology, biotechnology, medical chemistry or related disciplines, with possibly some experience in cell culturing, drug delivery with different materials. High motivation and strong dedication to research are considered basic requirements. The candidate will join an interdisciplinary and international group therefore the ability to cooperate and integrate in such an international environment will be positively considered. For questions concerning the research theme, please contact teresa.pellegrino@iit.it.

For administrative issues, please contact iulia.manolache@iit.it.