# DOCTORATE SCIENCES AND TECHNOLOGIES OF CHEMISTRY AND MATERIALS

## NANOSCIENCE RESEARCH THEMES

**1) Development of colloidal nanocrystals for photocatalytic applications**

**Tutor: Liberato Manna**

**Project description:** Colloidal semiconductor nanocrystals have been shown to be promising materials for a wide range of applications. This project will focus on nanocrystals and their exploitation in photocatalysis. One direction that will be pursued will be the fabrication of nanocrystal heterostructures able to provide efficient carrier separation and accessibility of such carriers to the external environment (as in a heterodimer geometry). They will have to fulfil several criteria: i) high photon-harvesting efficiency in the visible region, ii) small exciton binding energy, to facilitate splitting of the bound e-h pair into free carriers, and iii) high carrier mobility to enable fast migration of free carriers towards a reaction site, before the carriers can recombine; iv) chemical stability at operation conditions. Light-triggered reactions will then be tested, starting from model compounds to check the activity in the two semi-reactions (photoreduction and photooxidation) and then coupling them in a complete photocatalytic cycle. The activities will be conducted in the multidisciplinary environment of the Istituto Italiano di Tecnologia, specifically in the Nanochemistry and Optical Spectroscopy Labs, as well as in the Electron Microscopy and Materials Characterization Facilities.

**Requirements:** as a prerequisite, the ideal candidate must have a degree in materials science, chemistry, physics or related fields. Candidates with proficiency in nanomaterial synthesis and characterization are encouraged to apply. Experience in photocatalysis will be considered as a plus.

For further details concerning the research theme, please contact: liberato.manna@iit.it

**2) Hybrid antenna reactors based on colloidal quantum dots**

**Tutors: Liberato Manna, Andrea Toma**

**Project description:** New heterostructures encompassing low-dimensional semiconductors and optical metasurfaces -integrated into a single architecture- will be realized through the synergistic combination of colloidal synthesis and clean room-based nanofabrication. Within this context, the PhD candidate will implement and further optimize hybrid nanophotonic platforms, where light-matter interaction will be properly engineered to guide the design of new functional antenna-reactor systems, specifically conceived for photocatalytic applications. Extensive optical characterization, such as steady-state absorption and photoluminescence spectroscopy, will be carried out, while Raman measurements will be performed for real time in-situ monitoring photochemical reactions. The activities will be conducted in the multidisciplinary environment of the Istituto Italiano di Tecnologia, specifically in the Nanochemistry and Optical Spectroscopy Labs, as well as in the Electron Microscopy, Clean Room and Nanofabrication Facilities.

**Requirements:** as a prerequisite, the ideal candidate must have a degree in materials science, chemistry, physics or related fields. Candidates with proficiency in nanomaterial synthesis and characterization are encouraged to apply. Experience in micro/nano-fabrication technologies and/or optical spectroscopies will be considered as a plus.

For further details concerning the research theme, please contact: liberato.manna@iit.it and andrea.toma@iit.it

**3) Fabrication and investigation of infrared light-sources based on colloidal quantum dots**

**Tutor: Francesco Di Stasio**
**Co-Tutor: Hossein Roshan**

**Project description**: Colloidal Quantum Dots (QDs) are nowadays employed in consumer electronics products such as displays and lighting given their efficient emission of visible light. Nonetheless, recent developments allow QDs also to efficiently emit light in the short-wave infrared spectral (SWIR) region. Importantly, SWIR light-sources are of interest for a variety of applications such as hyperspectral imaging, night vision, telecommunication systems, point-of-care testing, LIDARS, etc…
The Photonic Nanomaterials group aims at developing light-emitting diodes (and other optoelectronic devices) operating in the SWIR spectral range exploiting the unique properties of QDs. In fact, QD chemistry enables on-demand tailoring of the light-emission properties of the final nanomaterial in combination with solution processing, thus enabling low-cost fabrication of light-emitting diodes (LEDs) and other optoelectronic devices.
Currently, the research group is focusing on the development of LEDs (either small or large-footprint ones) based on InAs or Hg-based QDs with emission between 900 and 1600 nm. In particular, colloidal indium arsenide (InAs) QDs are emerging as a promising substitute to heavy-metal containing compositions as they are fully RoHS-compliant and, thanks to recent progress in material synthesis, they can demonstrate stable and highly efficient emission.
The PhD candidate will focus on the synthesis of QDs and their implementation in LEDs carefully designed to obtain high external quantum efficiency and brightness. In addition, the PhD candidate will carry out detailed optical characterization of the synthesized QDs (steady-state and time-resolved photoluminescence, photon statistics, etc…) to correlate chemical properties with light-emission ones. Importantly, the PhD candidate will engage in collaborations with other group members, given the interdisciplinary nature of the proposed research theme, which requires a variety of skills for implementation.

**Requirements:** The ideal candidate must have a master's degree in Materials Science, Chemistry, Physics or related discipline. The candidate must be interested in a very interdisciplinary research activity encompassing chemistry, engineering and physics.

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**4) Development of innovative light-sensing applications based on colloidal quantum dots**

**Tutor: Francesco Di Stasio**
**Co-Tutor: Lucia Beccai**

**Project description**: The Photonic Nanomaterials and Soft BioRobotics Perception research groups are looking for a joint PhD candidate willing to undertake a challenging and interdisciplinary research project in the framework of the IIT flagship program "Technologies for Sustainability".
The project aims at developing novel optical sensors by integrating light-sources based on RoHS-compliant III-V semiconductor quantum dots (QDs) operating in the short-wave infrared. The sensors are intended for integration inadvanced soft-robotic platforms and are aimed at mechanical deformation detection and monitoring. In particular, the PhD candidate will investigate different venues to integrate QDs into soft sensing layouts (e.g., additive manufacturing, wet-chemistry approaches, film-deposition, etc…) and then assess the performance of the obtained light-based sensors.
On one hand the candidate will benefit from the knowledge and experience of the Photonic nanomaterials group in developing optoelectronic devices based on Quantum dots, while exploiting the expertise of the

Soft BioRobotics Perception research group in developing soft-robotic platforms and equipping them with novel functionalities.
Given the interdisciplinary nature of the research project, the selected candidate will join both research groups and will focus on developing and integrating such technologies with strong support from other peers, and other facilities at IIT.

**Requirements:** The ideal candidate must have a master's degree in one of the following areas: Materials Science, Chemistry, Chemical Engineering, Nanotechnology or Physics. The candidate must be interested in a very interdisciplinary research activity encompassing chemistry, engineering and physics.

For further details concerning the research theme, please contact: Francesco.distasio@iit.it and Lucia.Beccai@iit.it