RESEARCH THEMES

1) Advanced low-dimensional solutions for solar energy conversion and storage

Tutor: Ilka Kriegel

The global demand for clean energy encompasses two equally important issues: production, but also access to energy. Although solar energy is the most promising and abundant renewable source, for a more sustainable energy development its storage is equally crucial. A more effective storage makes it possible to respond both to the intermittent nature of the source and to fluctuations in consumption demand. A very attractive solution consists in combining the absorption and storage of energy in a single device, thus also avoiding the losses associated with the compartmentalization of these two functions. In this context, the miniaturization and manipulation of materials at the nanoscale can offer a concrete answer to these needs.

The proposed research project is based on the exploration and analysis of low-dimensional materials, in which light harvesting can combine with very competitive charge storage capacity through multiple charge transfer processes. The objectives of the project therefore concern both the synthesis and the fundamental characterization of a new set of nanomaterials, but also of their mutual interactions. Starting from these materials, in fact, the preparation of composite/hybrid systems is envisaged, which bring together and coordinate the electro-optical properties for the fabrication of innovative devices based on flow cell systems and electrolytic-like capacitors. The PhD scholarship is based on the FET Proactive project "LIGHT-CAP" (https://cordis.europa.eu/project/id/101017821) carried out by a research consortium with highly interdisciplinary and collaborative environment involving a number of different groups from Italy, Germany, Spain and Switzerland. Within this framework, the PhD student will acquire an important experience in the management of extra-laboratory activities and dissemination and communication activities. The international character of the project also includes the periodic interfacing with the consortium, which constantly stimulates discussions on the research plan. Likewise, the project encourages the possibility of visits and short research stages within the different groups involved. The PhD project will be carried out within the Functional Nanosystems group (https://www.iit.it/research/lines/functional-nanosystems). The interdisciplinary research approach of the Functional Nanosystems group located between nanochemistry, material science, spectroscopy and optoelectronics delivers a stimulating environment, representing the atmosphere of the Central Research Lab at IIT, one of the biggest research centers in Europe.

Requirements: We especially look for candidates with degrees in Chemistry, Materials Science, Physics or Engineering and who are interested in a very interdisciplinary research approach between materials science and characterization, optical microscopy and spectroscopy, electrochemistry and theoretical modeling.

We explicitly encourage female applicants for this position. For further details concerning the research theme and any related questions, please contact Ilka Kriegel (ilka.kriegel@iit.it).

2) Optoelectronics of plasmonic/semiconducting low-dimensional nanomaterials

Tutor: Roman Krahne

We aim to develop new concepts for optoelectronic devices based on photonic architectures and state-of-the-art nanomaterials such as colloidal nanocrystals and nanoparticles. One material class of great recent interest are low-dimensional semiconductor materials such as 2D layered perovskites. Based on a fundamental understanding of their optical and electrical properties, we will develop proof-of-concept devices for sensing, light emission, and signal processing.

The PhD candidate will work on time-resolved optical spectroscopy on these materials, their functionalization via surface chemistry and ion-exchange processes, and on nanofabrication of optical and electrical devices. We also aim to combine the nanomaterials with optical or plasmonic cavities for enhanced light emission and strong light-matter coupling.

The PhD position is hosted by Optoelectronics group (https://www.iit.it/it/web/optoelectronics) that is embedded in a highly stimulating and collaborative environment at the headquarters of the Italian Institute of Technology (IIT) in Genoa, Italy.

Requirements: The ideal candidate should have a degree in materials science, physics, chemistry or engineering, with a strong interest in the photophysics of nanomaterials and related device applications.

For further details concerning the research theme, please contact: roman.krahne@iit.it

3) Advanced electron microscopy of hybrid perovskite materials for energy applications (2 positions available)

Tutor: Giorgio Divitini

The green revolution will require significant breakthroughs in both energy production and end-use efficiency. In the last 10 years hybrid perovskites have emerged as a very promising class of materials with excellent optical and electronic properties, and have been successfully been employed in prototype solar cells for photovoltaic power generation and other optical systems, such as light emitting diodes (LEDs). The range of applications is very broad and include, for example, multi-layer solar cells improving power conversion efficiency over a single silicon junction (still the most established technology), semi-transparent solar cells for smart windows, and flexible solar cells. Similarly, high-brightness LEDs have been demonstrated and would enable significant energy savings in lighting. Some peculiar properties of hybrid perovskites, such as the flexibility in chemical composition and tolerance to defects, suggest that the scientific community has only started to scratch the surface on potential applications for this class of materials.

As new compounds are designed and as devices are tested in realistic settings, there is an increasing need to understand the properties and dynamic processes of hybrid perovskites at the nanoscale. Electron microscopy is a prime candidate for this analysis, due to the ability to access information on morphology, chemical composition and crystallography at the nanoscale. This is generally a very challenging process,

as hybrid perovskites are known to get damaged easily by the electron beam. Equipment, acquisition protocols and data analysis procedures all need to be optimised to unravel nanoscale structure and processes in these materials, making this project very rewarding.

This PhD position, which will be based in a group centred around electron microscopy, will include extensive use of the ThermoFisher Spectra 300 Transmission Electron Microscope just installed at the Italian Institute of Technology – a state-of-the-art instrument, among the top electron microscopes in the world -, which features high-efficiency detectors and class-leading electron optical capabilities. It will include experimental microscopy work, experiment design and the use of advanced algorithms for data analysis (predominantly python-based). The project is part of a strong existing collaboration between the Electron Spectroscopy and Nanoscopy research line at IIT and international partners (the University of Cambridge, the University of Rome Tor Vergata).

Requirements: The ideal candidate must have a Master's Degree or equivalent in one of the following areas: Material Science, Physics, Chemistry, or Chemical Engineering. Experience with electron microscopy and familiarity with python would be valuable but are not required.

For further details concerning the project, please contact: Giorgio.divitini@iit.it

4) Magnetic materials for curing cancer

Tutor: Teresa Pellegrino

The use of magnetic nanoparticles in various biomedical applications is gaining momentum thanks to the multifunctional properties of these peculiar nanomaterials. Among them, the use of magnetic nanoparticles as heat mediators in magnetic hyperthermia represents a new form of cancer therapy now in clinic for the treatment of Glioblastoma Multiforme tumor. With this method, tumor cells are burnt by increasing the temperature at the therapeutic range of 43-46°C generated by magnetic nanoparticles when exposed to a time varying field (a radiofrequency in the kHz regime). For this application, it is crucial to maximize the heating efficiency of magnetic nanoparticles under a kHz-radiofrequency of clinical use and under intratumoral conditions.

The PhD project aims at develop synthetic procedures for magnetic nanoparticles production yielding multifunctional magnetic nano-heterostructures specifically designed for magnetic hyperthermia, with focus on setting scaled-up preparative approaches. The PhD student will aim at tuning synthesis parameters to obtain magnetic materials at controlled composition, size, shape and crystallinity of the multi-domains heterostructures. Accurate physical/chemical studies will be carried out to correlate the magnetic /structural parameters to the magnetic hyperthermia heat efficiency not only in aqueous media but also under conditions that simulate the tumor microenvironment. The candidate will also aim at setting up scale up approaches for the gram scale production of nanomaterials and, at the same time, developing methodology that are eco-sustainable, to obtain nanoparticles/heterostructure by procedures at minimal environmental impact. The ideal candidate should be able to develop his/her own ideas on the present topics while having a well-defined attitude to collaborate within an international and interdisciplinary team.

Requirements: The ideal candidate must have a Master's Degree or equivalent in Chemistry or cognate discipline, with strong interest in synthesis of magnetic nanoparticles, structural characterization of nanomaterials, such as Transmission Electron Microscopy (TEM), X-Ray Diffraction (XRD), calorimetric measurements and data processing for Specific Absorption Rate (SAR) determination, high frequency hysteresis measurements, etc

For further details, please contact: Teresa.pellegrino@iit and iulia.manolache@iit.it

5) Materials for water technologies

Tutors: Giovanni Perotto, Athanassia Athanassiou, Despina Fragouli

In the last years, the development of novel water technologies able to deal with the water decontamination and the universal freshwater supply is a challenging task. For such actions are required novel processes and materials able to deal with the great variability of the common water pollutants and with the continuously renewable list of the emerging water pollutants, substances not commonly studied and monitored (e.g. nanoplastics, perfluorinated compounds, pharmaceuticals etc.), that may cause adverse ecological and human health effects.

This PhD activity will point to the development of novel processes and materials for the study of emerging pollutants and their interactions with other common pollutants, as well as with multi-functional porous materials fabricated ad hoc. The thesis will focus on natural based components, and will be adopted various materials engineering approaches in order to develop systems with desired structural and physicochemical properties that permit the desired interactions and entrapment of the targeted components. https://www.iit.it/research/lines/smart-materials

Requirements: the ideal candidate must have a Bachelor's Degree in one of the following areas: Materials Science, Chemical Engineering, Chemistry, Physics or Bioengineering.

For further details, please contact: Giovanni.Perotto@iit.it; Despina.Fragouli@iit.it; Athanassia.Athanassiou@iit.it