PhD Program in Bioengineering and Robotics

Curriculum: Bionanotechnologies

Research themes

The Bionanotechnology curriculum is related to basic and applied research programs oriented to the comprehension of fundamental phenomena at the nanoscale and to the application of nanotechnologies to bioengineering, biophysics, applied physics, material sciences and life sciences, and to the development of new technologies and approaches as a challenge for the next twenty years. Bionanotechnologies have a broad field of appeal, namely: from cells-to-chip and chip-to-cells technologies to nanobiosensors, from nanodiagnostics to advanced optical characterization and imaging tools, from intelligent drug delivery to artificial tissues, from functional nano-addressable surfaces to smart materials. Among others, research developments include developing new sustainable materials and approaches for packaging and electronics, and implementation of new microscopy techniques for investigating life at the nanoscale. As well, most of the applications are conceived starting from the IIT domains (Robotics, Nanomaterials, Lifetech, Computational Sciences) to numerous others, including technology transfer perspectives. The candidate will be immersed in the frontiers of science and technology.

International applicants are encouraged and will receive logistic support with visa issues, relocation, etc.

Development of Natural-Origin Thermoset and Thermoplastic Polymers and Their Composites for Green Electronics and Robotics

Tutor: Athanassia Athanassiou
Tutor's Affiliation: Smart Materials, IIT, Genova, https://smartmat.iit.it/home

Project Description: This fully funded PhD position will focus on the design, synthesis, and assessment of innovative, bio-based polymers and composites for use in next-generation sustainable technologies, such as green, flexible electronics and soft robotics.
The research will concentrate on thermoplastic and thermoset polymers derived from natural, renewable sources, developed using green chemistry principles and bioinspired approaches such as enzymatic interactions. The developed polymers will be combined into composite materials tailored for flexibility, conductivity, and environmental compatibility, targeting applications in emerging fields, such as biodegradable sensors, soft actuators, or eco-friendly wearable electronics, where conventional materials are unsustainable or toxic. The project will include life cycle assessments to quantify the environmental benefits of the developed systems over their entire lifespan.
The candidate will be part of the IIT Flagship of Technologies for Sustainability, through which will engage in a highly interdisciplinary research environment, strongly committed to innovative solutions for sustainable development. The candidate will have access to unique, cutting-edge laboratories and pre-industrial scale facilities, will enjoy a close mentorship and opportunities for international collaborations.

Candidate Profile

We are looking for a motivated PhD candidate with a Master's Degree in chemistry, chemical engineering, biotechnology, biology, material science, or a related field, with a strong commitment to sustainability and circular economy principles. Proficiency in English, both spoken and written, is required.
Experience in polymer synthesis, composite materials, or life cycle analysis (a plus but not mandatory)
Contacts:
Email: athanassia.athanassiou@iit.it

Development of Natural-Origin Hydrogels for Environmental Protection and Precision Agriculture

Tutor: Athanassia Athanassiou
Tutor's Affiliation: Smart Materials, IIT, Genova, https://smartmat.iit.it/home
Project Description: This fully funded PhD position focused on the design, development, and application of sustainable hydrogels derived from natural sources. The research will investigate hydrogels with varying degrees of cross-linking to optimize their performance as vehicles for the controlled absorption and release of bioactive compounds. The project aims to use the developed hydrogel systems in controlled absorption of pollutants or environmental agents, targeted delivery of nutrients or functional molecules to plants, soil, and marine organisms, with applications in precision agriculture, soil and water health, and biodiversity enhancement
The candidate will be part of the IIT Flagship of Technologies for Sustainability, through which will engage in a highly interdisciplinary research environment, strongly committed to innovative solutions for sustainable development. The candidate will have access to unique, cutting-edge laboratories and pre-industrial scale facilities, will enjoy a close mentorship and opportunities for international collaborations.
Candidate Profile
We are seeking a motivated candidate with a Master's degree in materials science, chemistry, physics, biology, Chemical engineering, environmental engineering, biotechnology, agricultural sciences, or a related discipline. Proficiency in English, both spoken and written, is required.
Laboratory experience in polymer synthesis, hydrogel development, biodegradability or environmental testing (desirable but not mandatory)
Contacts:
Email: athanassia.athanassiou@iit.it

Smart Microscopy with Event-Based Detectors and Adaptive Imaging Integration

Tutors: Giuseppe Vicidomini
Tutors Affiliation: Molecular Microscopy and Spectroscopy, Istituto Italiano di Tecnologia

Project Description

The field rapidly evolves toward *smart* microscopy, where imaging systems can autonomously analyse data in real time and adapt acquisition parameters accordingly. During acquisition, these systems rely on feedback loops that respond to detected events by adjusting key settings, such as imaging speed, resolution, or modality. This smart, adaptive approach enables researchers to maintain optimal imaging performance without the usual compromises between field of view, temporal and spatial resolution, sample health, or signal-to-noise ratio.

This PhD project explores the development of a *smart* microscopy platform that leverages novel event-based detectors, including asynchronous read-out single-photon avalanche diode (SPAD) array detectors and neuromorphic cameras, within a polyfunctional microscope architecture combining both wide-field and laser-scanning modalities. Inspired by biological vision, neuromorphic cameras detect pixel-level brightness changes asynchronously, enabling extremely high temporal resolution while minimising redundant data acquisition. Their unique capabilities make them ideal for real-time detection of fast or rare events across large fields of view. In contrast, asynchronous SPAD array detectors enable photon-resolved microscopy. This highly informative imaging technique captures rich spatial and temporal information at the single-photon level, though over a more limited field of view.

The system will operate in a *smart* feedback-driven mode. (i) Wide-Field Monitoring: The neuromorphic camera continuously scans the entire sample for dynamic events; (ii) Targeted Response: Upon event detection, the system will automatically switch to a laser-scanning modality and redirect imaging to the region of interest.

The PhD candidate will be involved in the optical integration, control software development, and algorithm design necessary for real-time data processing and system-level adaptation. In particular, the candidate will carry out the following tasks: (i) Literature Review – Perform a critical analysis of the current applications of event-based cameras and SPAD arrays in advanced microscopy; (ii) Optical Design – Acquire practical experience in assembling and aligning multifunctional fluorescence microscopes that integrate wide-field and laser-scanning architectures; (iii) Image Analysis and Reconstruction – Develop or adapt algorithms to reconstruct conventional images from asynchronous event streams and design feedback mechanisms for adaptive, smart microscopy; (iv) System Control – Implement innovative triggering strategies that enable automated switching between imaging modalities in response to detected biological events.

Requirements

- Solid programming skills (Python or equivalent)
- Background in image analysis, computer vision, or real-time signal processing
- Basic knowledge of optics and fluorescence microscopy
- Interest in AI-driven scientific instrumentation
- Degree in physics, engineering, computer science, or a related field

References

D. Mahecic, et al., Nat. Methods (2022) https://doi.org/10.1038/s41592-022-01589-x
G. Tortarolo, et al., Adv. Photon. (2024) https://doi.org/10.1117/1.AP.6.1.016003
R. Guo, et al. Light Sci. Appl. (2024) https://doi.org/10.1038/s41377-024-01502-5

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