PhD Program in Bioengineering and Robotics

Curriculum: Bionanotechnology

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.

1. Integration of innovative optical sensors in a robotic platform for plant and soil analysis

Tutors: Francesco Di Stasio, Claudio Semini

Tutors Affiliation: Photonic nanomaterials, Istituto Italiano di Tecnologia, (https://photnano.iit.it/home), Dynamic Legged Systems, Istituto Italiano di Tecnologia, (https://dls.iit.it/)

Project Description:

The Photonic Nanomaterials and Dynamic Legged Systems 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 integrating novel optoelectronic sensors and light-sources based on RoHS-compliant III-V semiconductor quantum dots operating in the near-infrared in an advanced robotic platform for automatic monitoring of soil and plant quality (pollutants, chemical species, fertilizers, etc…). 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 Dynamic Legged Systems laboratory in developing robotic platforms and equipping them with novel functionalities.

Finally, yet importantly, the candidate will also test the final robotic integrated system in real-world conditions with support from external partners.

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.

References:

1) H. Bahmani Jalali, L. De Trizio, L. Manna, F. Di Stasio "Indium arsenide quantum dots: an alternative to lead-based infrared emitting nanomaterials" Chemical Society Review, 2022.
2) P. Guadagna, M. Fernandes, F. Chen, A. Santamaria, T. Teng, T. Frioni, D. G. Caldwell, S. Poni, C. Semini, M. Gatti, "Using deep learning for pruning region detection and plant organ segmentation in dormant spur-pruned grapevines" Precision Agriculture, 2023.

Requirements: MSc degree in electronic engineering, robotics, bioengineering, materials science

References: Max 3 refs

Contacts: francesco.distasio@iit.it, Claudio.semini@iit.it

2. Bioconversion of Spent Biomass for Sustainable Material Development

Tutors: Athanassia Athanassiou

Tutors Affiliation: Smart Materials, IIT, Genova, https://smartmat.iit.it/home

Project Description:

This fully funded PhD position focuses on the biological conversion of spent biomass from the food and beverage industry into high-value products and sustainable materials. The project will explore the transformation of waste, such as citrus peels, spent coffee grounds, brewer's spent grain, and yeast, into valuable fungal biomass. This biomass will serve as a source for enzymes, single-cell proteins, lipids, polysaccharides, and extracellular polymeric substances.

Research will aim to develop composite biomaterials combining mycelium and spent biomass, with an emphasis on materials rich in chitin, potentially applicable in fields such as flexible electronics. By the third year, the goal is to create high-value materials based on reorganized plant biomass and recovered building blocks (proteins, lipids, and polysaccharides). The selected candidate will join a collaborative research environment and contribute to eco-friendly material innovation under the *Technologies for Sustainability* flagship of IIT's strategic plan, supporting the UN Sustainable Development Goals 9, 11, and 12.

Requirements:
Candidates should hold a Master's Degree in biotechnology, material science, chemistry, chemical engineering, or a related field, with a strong commitment to sustainability and circular economy principles. Proficiency in English, both spoken and written, is required.

References: KB Bonga, et al., Mycelium Agrowaste-Bound Biocomposites as Thermal and Acoustic Insulation Materials in Building Construction, Macromolecular Materials and Engineering, 2300449 (2024)

L Bertolacci, L Goldoni, A Zych, A Athanassiou, Biocatalytic oxidation of polyethylene by Agrocybe aegerita mycelium, Polymer Degradation and Stability 199, 109911 (2022)

Contacts:
Email: athanassia.athanassiou@iit.it

3. Recycling Strategies for Plastic Waste and Sustainable Material Development

Tutors: Athanassia Athanassiou

Tutors Affiliation: Smart Materials, IIT, Genova, https://smartmat.iit.it/home

Project Description:

This PhD project focuses on developing advanced recycling strategies for plastic waste, targeting improvements in mechanical properties and environmental sustainability. It will examine the mechanical recycling of plastics, such as LDPE, PET, and PA6, and their composites through multiple cycles to observe changes in material properties. To enhance strength and flexibility, green additives and fillers will be introduced during melt extrusion, followed by compression or injection molding, with comprehensive analysis of thermomechanical and chemical properties.

The project will also address biopolymer waste, including biopolyesters, reprocessed with green plasticizers and additives to assess their suitability for sustainable products. Methods like melt extrusion, cast film extrusion, and blow extrusion will be used. The candidate will participate in life cycle assessments (LCAs) to evaluate environmental and energy impacts across various recycling scenarios, supporting innovations in sustainable packaging. The project aligns with IIT's *Technologies for Sustainability* flagship initiative.

Requirements:
Candidates should have a Master's Degree in Material Science, Bioengineering, Chemical Engineering, Chemistry, Physics, or Biology. Proficiency in English, both spoken and written, is required.

References G Scoponi, N Francini, A Athanassiou, Production of green star/linear PLA blends by extrusion and injection molding: Tailoring rheological and mechanical performances of conventional PLA, Macromolecular Materials and Engineering 306 (5), 2000805 (2022)

AA Barmpaki, UC Paul, M Nardi, A Athanassiou, Eco-friendly Blends of Polylactic Acid and Polyhydroxybutyrate Enhanced with Epoxidized Soybean Oil Methyl Ester for Food-Packaging Applications, ACS Applied Polymer Materials 6 (15), 8997-9007 (2024)

Contacts:
Email: athanassia.athanassiou@iit.it

4. Bioplastics Biodegradation by Engineered Enzymes

Tutors: Marco De Vivo, Athanassia Athanassiou

Tutors Affiliation: Molecular Modeling and Drug Discovery & Smart Materials, IIT, Genova, https://mmdd.iit.it/, https://smartmat.iit.it/home

Project Description:

We are offering a fully funded PhD position under the ***Technologies for Sustainability*** flagship of IIT's strategic plan. The research will focus on engineering enzymes to enhance their hydrolytic activity on polyester bioplastics, aiming to accelerate biodegradation processes. The project is centered on experimental generation and validation of enzyme variants, closely integrated with computational predictions from experts in atomistic simulations and machine learning-based enzyme design. Key goals include increasing enzyme thermostability, improving biopolymer recognition, and ultimately enhancing enzymatic biodegradation efficiency.

The PhD candidate will be responsible for experimental work, involving expression, purification, and characterization of both wild-type and mutated recombinant enzymes. They will assess enzyme activity using biophysical, biochemical, and structural biology techniques, establishing assays and resolving crystal structures. This hands-on work will synergize with computational studies within a multidisciplinary team, striving to design and validate gain-of-function mutations for enhanced bioplastic degradation. The candidate will then evaluate bioplastic degradation, analyzing morphological changes and degradation products.

The student will work across the Smart Materials lab (Dr. Athanassiou) and the Molecular Modeling and Drug Discovery lab (Dr. De Vivo), with collaboration from IIT's Structural Biophysics facility (Dr. Girotto), as well as other parallel projects under the *Technologies for Sustainability* flagship.

Requirements:
Candidates should hold a Master's Degree in biotechnology, material science, chemistry, chemical engineering, or a related field, with a strong interest in sustainability and circular economy. Proficiency in English, both spoken and written, is required.

Contacts:
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