UNIVERSITÀ DEGLI STUDI DI GENOVA

ISTITUTO ITALIANO DI TECNOLOGIA

Università degli Studi di Genova – Istituto Italiano di Tecnologia

Corso di Dottorato "Bioingegneria e Robotica"

Curriculum "Bionanotechnologies

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Ciclo XXXIII

5 positions available with scholarship

Research Themes

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Introduction

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 characterization and imaging tools, from intelligent drug delivery to artificial tissues, from functional nano-addressable surfaces to smart materials. Among others, research developments include elucidating molecular mechanisms behind degenerative (neuro or oncological) misfunctioning of biological systems within the biomedical scenario. As well, most of the applications are conceived starting from the IIT platforms (Energy, Biomedical, Robotics) to numerous others, including technology transfer perspectives. The candidate will be immersed in the frontiers of science and technology.

Science and technology developments aim

- to advance the exploitation of nanostructures, fabricated by nanotechnological approaches, as building blocks for engineered self assembly architectures across multiple length scales, from the molecular level up to the macroscopic world and the development of new strategies related to the utilization of micro and nanomanufacturing to produce Micro Electric Mechanical Systems (MEMS), micro electrodes and scaffolds with dimensions comparable to cells and innovative plasmonic devices for different applications;
- to design, realize and utilize advanced methodologies and instrumentations within the framework of optical spectroscopy and microscopy, scanning force microscopy and optical nanoscopy, oriented to the study and characterization of nanostructured, biological and hybrid materials/specimens at the nanoscale - i.e. having at least one of the here spatial dimensions controllable at the nanometric or subnanometric scale. The focus is on the development of new strategies for the assembly of nano-systems able to realize new nanoparticles and nanostructured environments, to design and realize architectures to characterize materials, both artificial and biological, within a scale ranging from single molecules or particles or nanostructured complexes to the full biological scale, molecules, cells, tissues, organs and human bodies. As well several projects we aim integratingdifferent design and knowledge levels from a 2D (x,y) to a 4D (x, y, z, t) space.
- to take advantage of nanotechnology for the development of new materials based on polymers to produce smart multifunctional devices easily processable at scalable-low cost, with a wide range of exciting and outstanding applications. Nanoparticles and Nanocomposites are conceived, here, for tailoring the properties of fibrous & non-woven & nano/micro structured materials - e.g. cellulose fibers and polymer Foams. The development of all-polymer composites with tailored properties allows controlling surface wettability, mechanical properties and antibacterial activity among others. Developed nanocomposites - polymer matrices incorporating nanofillers - will be endowed of tailored magnetic properties, conductivity, thermomechanical properties and surface wettability towards the growing demand of striking performances in bionanotechnologiy.

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

1. Self-growing natural composite materials based on fungi

Tutor: Athanassia Athanassiou

Department: Smart Materials (IIT)

https://www.iit.it/lines/smart-materials

Description: This PhD activity will point to the controlled development of natural composite materials based on the fungal mycelium. Mycelium is the main body of the fungi that grows underground and is fed upon various organic nutrients. We have recently demonstrated that we can grow mycelium-based membranes of tunable mechanical properties by changing their feeding substrates. This activity will deal with further development of such materials towards 3D constructs and incorporation of various nanoparticles. The self-growing natural composite materials will be used as fibrous substrates for further development of smart bio-composites (Strengthening of natural polymers, Absorbers of pollutants in water, etc.), and natural self-growing electric circuits platforms as well as natural self-grown capacitors for sensors applications.

Requirements: The ideal candidate must have a Bachelor's Degree in one of the following areas: Biotechnology, Bioengineering, Material Science, Biology, Physics and Chemistry with biological specialization.

Contacts: athanassia.athanassiou@iit.it

2. Sustainable materials from non-food natural resources

Tutors: Athanassia Athanassiou, Giovanni Perotto

Department: Smart Materials (IIT)

https://www.iit.it/lines/smart-materials

Description: This PhD activity will be focus on the development of novel biodegradable and natural polymeric composites through a top down approach. It will include transformation of vegetable wastes, and other organic waste primary from food industry, and non-food crops directly into natural polymeric composites by non-toxic solvent processing methods. It will also include transformation of animal products like wool, chicken feather or silkworm cocoons into protein-based polymeric materials.
The developed sustainable materials can be used and further engineered for durable coatings, packaging, constructions, textiles and all sectors that conventional plastics are currently used, minimizing the use of non-sustainable natural resources (i.e. oils) and also the accumulation of non/degradable and toxic wastes.

Requirements: The ideal candidate must have a Bachelor's Degree in one of the following areas: Chemistry, Material Science, Biochemistry, Chemical or Bio Engineering.

Contacts: athanassia.athanassiou@iit.it, giovanni.perotto@iit.it

3. Sustainable and interacting food packaging

Tutor: Ilker Bayer

Department: Smart Materials (IIT)

https://www.iit.it/lines/smart-materials

Description: Through millions of years of evolution Nature has created an array of nanostructured surfaces that possess a wide range of wetting properties including ever-dry, sticky or wettable self-cleaning structures. Both plants and animals including fish have such surfaces that help them feed, survive harsh environmental conditions and avoid predators. Inspired by these systems, research on the development of synthetic surfaces that can function in similar ways has gained tremendous impetus. The potential applications in bio-nanotechnology have various aspects such as biofouling prevention, protein adsorption, cell adhesion.
This PhD project will focus on designing and developing such bioinspired nanostructured surfaces with polymer nanocomposites as coatings or free standing materials using novel fabrication techniques so that desired multi-scale surface features can be produced. Fabrication methods that can be transformed into large scale industrial platforms will be given priority. The candidate will incorporate various types of chemical approaches such as self-assembly, in-situ polymerization, substrate pretreatment etc. to functionalize the surfaces in order to tune their wetting and adhesion properties. Particular attention will be given to fabricate strong and wear-resistant surfaces. By proper combination of surface texturing and chemistry, surfaces with desired wetting properties will be fabricated ranging from non-wetting to sticky but self-cleaning.

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

Contacts: ilker.bayer@iit.it

4. Single Molecule Detection: the ultimate biosensor issue

Tutor: Francesco De Angelis

Department: Plasmon Nanotechnologies (IIT)

https://www.iit.it/lines/plasmon-nanotechnologies

Description: The fabrication of nanostructures for extremely large electric-field enhancement has become increasingly important over the last few years with the aim to detect molecules in highly diluted liquids, and/or to record the Raman spectra of a single molecule. Within this context, the realization of complex 3D plasmonic nanostructures integrated in cutting-edge devices represents a multidisciplinary key activity at the core of most research efforts in nanoscience and technology. PhD activity will demonstrates the possibility to conceive and realize innovative 3D metallic nanostructures, endowed with multi-tips and decoupled from the substrate by means of standing silicon pillars. The proposed architecture can offer new and unconventional properties such as the realization of giant electric field confinement and enhancement in a multi-spots bio-sensing platform. The possibility to increase the device active regions will improve the overall spatial efficiency leading to interesting perspectives not only in SERS but also in hyperspectral Raman imaging. The proposed work is part of a research project devoted to the innovative fabrication and optical characterization of complex plasmonic nanostructures made of noble metals with various shapes and spatial arrangements. The candidate will acquire a good clean room expertise combined with spectroscopic characterization (both in the VIS and IR spectral range), working in a multidisciplinary environment across nanofabrication and nano-optics.

Requirements: Candidates should have a M.D. in Physics, Material Science or Engineering, better if accomplished with a good background in electron beam lithography technique and/or FTIR measurements.

Contacts: francesco.deangelis@iit.it

5. Plasmonic nanostructures for all-optical computing

Tutor: Andrea Toma

Department: Plasmon Nanotechnologies (IIT)

https://www.iit.it/lines/plasmon-nanotechnologies

Description: Optical computing is a new coming field dealing with data manipulation for ultra-fast communication technology. In the attempt of improving the operational capacity of photonic circuits, plasmonics can offer an elegant way for fastening data-elaboration units without signal dispersion. PhD activity will demonstrate the possibility to conceive and realize innovative plasmon-assisted optical logic gates. Basing on the concepts of bonding/anti-bonding and bright/dark plasmonic modes, it will be possible to design and completely characterize the far-field behavior of such devices paving the way for ultrafast signal manipulation and/or multiplexing.
The candidate will acquire a good clean room expertise combined with spectroscopic characterization (both in the VIS and IR spectral range), working in a multidisciplinary environment across nanofabrication and nano-optics.

Requirements: Candidates should have a M.D. in Physics, Material Science or Engineering, better if accomplished with a good background in electron beam lithography technique and/or FTIR measurements.

Contacts: andrea.toma@iit.it

6. Nanostructured surfaces for neuronal network interfaces

Tutor: Francesco De Angelis

Department: Plasmon Nanotechnologies (IIT)

https://www.iit.it/lines/plasmon-nanotechnologies

Description: Research on human neuronal signaling is the subject of a very large community, but progresses face a dense multi-scale dynamics involving signaling at the molecular, cellular and large neuronal network levels. Whereas the brain capabilities are most likely emerging from large neuronal networks, available electrophysiological methods limit our access to single cells and typically provides only a fragmented observation, on limited spatial/temporal scales. We propose the development of an innovative electro-plasmonic platform will provide a radically new path for real time neuro-interfacing.
This is achieved by exploiting an innovative nanofabrication method able to realize 3D nanostructures which can work at the same time as nanoelectrodes and as amplifiers for spectroscopic signals. These structures will be integrated on CMOS multi-electrode arrays designed to manage multi-scale measurements from the molecular level up to network level on several thousand of measurement sites.

Requirements: This research theme strongly relies on nanofabrication advanced techniques and candidates should have a master in Physics, Electronic Engineering or similar. Background in Biophysics is strongly appreciated.

Contact: francesco.deangelis@iit.it

7. Novel nano-size materials for energy storage

Tutor: Remo Proietti Zaccaria

Department: Plasmon Nanotechnologies (IIT)

https://www.iit.it/lines/plasmon-nanotechnologies

Description: This interdisciplinary project aims at the development of novel materials specifically designed for energy storage. The candidate will exploit both bottom-up and top-down fabrication techniques for the fulfilment of his/her tasks, together with deep electrochemical characterization.
As important task to improve the electrochemical properties of the fabricated materials, the candidate will be requested to elaborate simple mathematical structural modelling to be verified with experimental data. Prior knowledge of Comsol FEM software will be considered an advantage

Requirements: Applicants should hold a master degree within a relevant discipline. A suitable background would be, physics, chemistry, engineer, material science, electrochemistry or similar. Experience with electrochemistry and programming will be favourable. Publications and any other work the applicant wishes to be taken into account must be enclosed. Joint works will be considered provided that a short summary outlining the applicant's contributions is attached.

The application must include a statement of purpose related to the present call. This statement should be precise and brief, and states the candidate's academic and research interests. The applications must also include a motivation letter, CV, diplomas, and reference letters.

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