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 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.

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

1. Multi-Parameter Scanning Microscopy

Tutor: Prof. Alberto Diaspro and Dr. Giuseppe Vicidomini

Department: Istituto Italiano di Tecnologia, "Nanoscopy and NIC@IIT" and "Molecular Microscopy and Spectroscopy" labs.

Description: Light beam scanning microscopy – confocal or non-linear [1] – allows (x-y-z-t) four-dimensional (4D) functional imaging of biological systems. It typically focuses laser beams into a tiny volume of the sample and repetitevely raster scans this probe volume across the sample to form a 4D image, which describes the spatial and temporal distribution of same sample's properties. Since, different light-matter interactions can be explored, scanning microscopy has the unique property to correlate a plethora of structural and function information. One the most used light-interaction is fluorescence. By simply recording the fluorescence light response (intensity image) from specifically

labelled molecules, one can visualize the sub-cellular structures with few hundred nanometres spatial resolution, or with few tens of nanometres if combined with STED microscopy [2]. Advanced photons detection schemes give access to fluorescence spectrum, lifetime and anisotropy images, thus to biochemical and molecular structural information. On the other side, absorption and scattering mechanisms can provide structural information without the need of labelling probes (label-free). This plethora of information is normally obtained sequentially, since any probing mechanisms requires a different detector (with different characteristics) and/or a different acquisition scheme, and/or a different analysis of the signal. However, biological systems are highly heterogeneous in time, which makes a sound correlation of all these parameters in living system almost impossible.

Aim of this project is to explore novel photon detectors able to extract simultaneously the signals stemming from different contrast mechanisms and to implement data acquisition and signal processing architectures [3] able to correlate in real-time all the information potentially accessible with a scanning microscope. This has a key impact in oncological and neurological applications.

Requirements: We are seeking a highly motivated and talented PhD student to join our interdisciplinary research teams. The successful candidate should have: (i) a degree in physics, engineering (or a related field); (ii) programming skills in MATLAB/LabView/C# for device control and synchronization; (iii) ability to work in an interdisciplinary team, willingness to work outside core expertise.

References:

[1] Diaspro A., Confocal and two-photon microscopy: foundations, applications, and advances. Wiley-Liss, New York (2002)
[2] Vicidomini G., Bianchini P., Diaspro A., STED super-resolved microscopy, Nat. Methods, 15:173–182 (2018)
[3] Castello M., Tortarolo G., Coto Hernández I., Deguchi T., Diaspro A., Vicidomini G., Removal of anti-Stokes emission background in STED microscopy by FPGA-based synchronous detection, Rev. Sci. Instrum., 88(5): 053701 (2017)

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For further info: https://www.iit.it/phd-school/

For application on line: https://www.studenti.unige.it/postlaurea/dottorati/XXXIV/

2. Bio-scaffolds for controlled delivery of active substances and drugs

Tutor: Athanassia Athanassiou

Department: Smart Materials (IIT), https://www.iit.it/lines/smart-materials

Description: recent trends in biomedical and pharmaceutical research indicate that natural polymers are increasingly explored as vehicles for drug delivery. Being biocompatible and biodegradable, they can be absorbed into the body fluids without any toxic effects This PhD activity

will deal with the development of bio-scaffolds of different geometries and structures based on natural polymers, and especially polysaccharides and proteins, in order to deliver incorporated natural active compounds or synthetic drugs in a highly controlled manner. Strategies to combine hydrophobic and hydrophilic drugs in common natural matrices, and their controlled simultaneous delivery will be followed. The delivery of the active compounds will be done through inhalation, ingestion or skin contact, and therefore, dedicated scaffolds will be obtained for each application, such as micro or nano-beads, fibrous mats, films, etc. The improvements of the bioavailability of the delivered substances will be also targeted.

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

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3. Nanoplastics in water and their interactions with other pollutants: effects in biological systems

Tutor: Athanassia Athanassiou

Department: Smart Materials (IIT), https://www.iit.it/lines/smart-materials

Description: nanoplastics are emerging water pollutants which can easily interact with various chemicals and pass to the food chain, with so far unknown health effects. Due to the difficulty to recover nanoplastics from the aquatic environment the research in this field is pretty limited so far. This PhD activity will point to the fabrication of nanoplastics by laser ablation of various polymer targets in liquids in order mimic the nanoplastic pollutants present in aquatic environments. After the complete characterization of the fabricated nanoplastics, their affinity with common and emerging water pollutants, such as pesticides, drugs, dyes, heavy metal ions, flame retardants etc. will be investigated, in order to define the most stably interacting systems. The interactions of nanoplastics and nanoplastics-pollutants combined systems with cells and tissues will be then studied in order to evaluate the effects that such pollutants can have to the living organisms.

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.

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4. Microdevices for transdermal delivery and skin investigation

Tutor: Athanassia Athanassiou

Department: Smart Materials (IIT), https://www.iit.it/lines/smart-materials

Description: in the past few years, alternative methods to model tissue diseases and design therapeutic strategies are attracting researchers' interest, thanks to the high versatility achievable with developing biomedical technologies and the persistent ethical issues related to the animal use. Within this contest, this PhD activity will focus on the design and development of microdevices for the assessment of transdermal drug delivery and nanomaterial skin toxicity. The device fabrication might be exploited via 3D printing, replica molding, and/or micropatterning. The validation of the design will be performed via diffusion studies, through model or artificial tissues, comparing the results with gold standard procedures (Franz cells) as well as microscopy studies. Further implementation of the system aiming to integrate temperature or pH sensitive-materials within the device will be also considered.

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

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