Curriculum Bionanotechnology

Research themes

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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 nanodiagnosics 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. New Developments in Advanced Light Microscopy

Tutor:
Giuseppe Vicidomini

Department:
Molecular Microscopy and Spectroscopy, IIT, Genova
https://www.iit.it/research-lines/molecular-microscopy-and-spectroscopy
and https://vicidominilab.github.io

Description:
The processes of Life are naturally dynamic in space and time from the molecular to the organismal level. Among the different imaging techniques, light microscopy is the only one that potentially can work across this full scale of biological organisation. Ideally, light microscopy is able to visualise the inner workings of proteins, protein complexes, organelles, cells, tissues, organs and whole organisms. However, in practice each specific microscopy techniques poses some fundamental limitations in terms of spatiotemporal resolutions/ranges, labelling, invasiveness, and information contents.

The core research of our group (Molecular Microscopy and Spectroscopy, MMS) is the design, development, and validation of novel optical, biological and computational tools that allow the modern biologists to peer inside living cells with unprecedented spatiotemporal resolutions/ranges, minimal invasiveness, and augmented information content. This goal can be achieved only by working across many disciplines, from physics to engineering, from computer science to biology.

The PhD student will be fully integrated in this general mission and his/her specific project will be design according to his/her background and skills. Current general projects, among which the candidate will contribute, consist in (i) the implementation of super-resolution laser scanning microscopy techniques (e.g., STED and image-scanning microscopy) for deep- and multi-parameter imaging which leverage a unique class of single-photon detector array recently introduce by our group; (ii) the realisation of single-molecule spectroscopy/imaging/tracking architectures which combines nanometre 3D spatial resolution, high-throughput, and ability to quantitatively study the function and structure of different multi-protein machineries/bio-molecules; (iii) the realisation of a wide-field based microscopy technique for large field-of-view and fast imaging based on non-conventional illumination and detection schemes; (iv) design of computational tools in the context of the above projects for improving the imaging quality, and/or reconstruct the finale images, and/or decodes from the dataset the maximum number of specimen information. The PhD student will work in the realisation of these novel methods in order to investigate the most exciting unresolved question from Life sciences.

The PhD student will benefit significantly from the active collaborations of the MMS group with the several computational and photonics groups of the Istituto Italiano di Tecnologia.

Requirements:
The project is extremely multi-disciplinary, and it involves many different aspects. Hence, the position is open to candidate having a Master’s degree in one of the following areas: Physical Science, Computer Science, and Engineering. Ability and
motivation to work independently as well as collaboratively in an interdisciplinary team is very important. Good English language speaking and writing skills are required. For Computer Science candidates good coding skills (preferably in Phyton) and knowledge in Artificial Intelligence are important.

References:

Contacts:
Email: giuseppe.vicidomini@iit.it
2. Investigation of Biomolecular Processes with Advance Light Microscopy

Tutor: Giuseppe Vicidomini

Department: Molecular Microscopy and Spectroscopy, IIT, Genova
https://www.iit.it/research/lines/molecular-microscopy-and-spectroscopy
and https://vicidominilab.github.io

Description:
The processes of Life are naturally dynamic in space and time from the molecular to the organismal level. Among the different imaging techniques, light microscopy is the only one that potentially can work across this full scale of biological organisation. Ideally, light microscopy is able to visualise the inner workings of proteins, protein complexes, organelles, cells, tissues, organs and whole organisms. However, in practice each specific microscopy techniques poses some fundamental limitations in terms of spatiotemporal resolutions/ranges, labelling, invasiveness, and information contents.

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The PhD student will be fully integrated in this general mission and will use the most advanced optical methods and analysis tools developed by the group, and available at the Italian Institute of Technology, to answer fundamental questions for RNA biology and/or neuroscience. As example, our group recently developed a fluorescence fluctuation spectroscopy (FFS) technique based a novel single-photon detector array. This novel system allows to implement several FFS techniques (such as spot-variation fluorescence correlation spectroscopy, pair-correlation analysis, and image-derived mean squared displacement analysis) combined with different time-resolved spectroscopy method (such as fluorescence lifetime), thus opening to high-information content experiments for deciphering biomolecule dynamics and interactions in living-cell. The group validated the system on test samples, and now is aiming to apply the method to study RNA-based biomolecules and synaptic proteins. A particular attention will be dedicated to question concerning the role of non-coding RNA in gene expression control.

The PhD student will benefit significantly from the active collaborations of the MMS group with the several groups of the LifeTech domain within the Istituto Italiano di Tecnologia.

Requirements:
The project is open to candidate having a Master’s degree in one of the following areas: Engineering, and Biological Science. Ability and motivation to work independently as well as collaboratively in an interdisciplinary team is very important. Good English language speaking and writing skills are required. Previous
research experiences in cell culture, cellular transfection, and fluorescence microscope are very important.

References:


Contacts:
Email: giuseppe.vicidomini@iit.it
3. Smart biocomposites for drug delivery and active skin wound healing

**Tutors:** Athanassia Athanassiou, Giulia Suarato  
**Department:** Smart Materials (Istituto Italiano di Tecnologia),  
[https://www.iit.it/research/lines/smart-materials](https://www.iit.it/research/lines/smart-materials)

**Description:**  
With the tendency of the European population to grow older, the chances of developing age-related chronic diseases, such as diabetes, cardiovascular, and neurological pathologies become more frequent. Tightly associated with ageing are chronic wounds (*i.e.* diabetic foot ulcers, bedsores, and non-healing ulcers), as a consequence of limited blood circulations, persistent inflammation, and bacterial infections. On top of negatively affecting a patient’s quality of life, chronic wounds require long treatments, and a large amount of medical wastes, thus rising the need for more efficient and environmentally safe solutions.

Within this frame, the Smart Materials group has gained extensive expertise in developing smart patches, based on the use of naturally-derived proteins and polysaccharides, able to actively deliver biological compounds and sustain the skin wound healing process and the tissue regeneration.

The aim of this PhD research program is the further development of smart biocomposites, based on different biocompatible and biodegradable polymeric materials in combination with biologically active molecules, towards a multifunctional platform for skin wound healing. Various materials architectures will be exploited (e.g. fibers, micro- and nanoparticles, hydrogels, films and combinations thereof) in order to optimize the patch physico-chemical properties, enhance its coupling to the wound site, and tune the drug release profile and the antibacterial properties. Strategies for wound healing monitoring will be also explored.

The student will have the opportunity to develop research projects under the novel Sustainability Initiative promoted within IIT. In particular, the work will focus on the Sustainable Development Goal number 3 (Good Health and Well Being, SDG3), with the challenging aim of finding advanced and environmentally-friendly therapies to tackle the chronic wound healing problem.

**Requirements:**

The ideal candidates are students with a Bachelor’s Degree in one of the following areas: Biotechnology, Bioengineering, Material Science, Biology, Physics and Chemistry with biological specialization. The candidates should preferably have further experience in the field of sustainable materials in the form of summer internships or preparation of undergraduate research projects. Good experimental and English language speaking and writing skills are required.

**References:**

• Contardi et al., Electrospun Polyvinylpyrrolidone (PVP) hydrogels containing hydroxycinnamic acid derivatives as potential wound dressings, *Chemical Engineering Journal* (2020)
• Suarato et al., From fabric to tissue, recovered wool keratin/polyvinylpyrrolidone biocomposite fibers as artificial scaffold platform, *Materials Science and Engineering C* (2020)

Contacts:

athanassia.athanassiou@iit.it
4. Micro/Nano particle fabrication for drug delivery and theranostics

Tutor:
Paolo Decuzzi, PhD

Department:
Laboratory of Nanotechnology for Precision Medicine, IIT, Genoa
https://www.iit.it/research/lines/nanotechnology-for-precision-medicine

Description:
In the context of drug delivery, various formulation strategies like liposomes, niosomes, polymeric micelles and nanoparticles have been developed and optimized for achieving biodegradability and site-specific action. These particle formulations are typically spherical and rely on self-assembly through bulk emulsion, or microfluidics for synthesis. As a result, the most studied formulation properties have been particle hydrodynamic size and surface electrostatic potential. More recently, the aspect ratio (AR) and mechanical stiffness of nano/micro particles are emerging as important formulation variables to fine tune biomedical performance. Within this context, polymeric hydrogel microparticles (HMP) are garnering attention as they can be engineered into different morphologies. Numerous methods such as imprint lithography, particle replication in non-wetting templates, PVA film stretching and nanoimprint lithography and continuous flow lithography have been explored for anisotropic particle synthesis. In this PhD course, photolithographic techniques and microfluidics will be combined together to realized anisotropic multiscale microhydrogels with a size range of 1 – 10 μm with varied aspect ratios and different payloads, including small molecules, liposomes and polymeric nanoparticles. These systems will be used for drug delivery and theranostics applications.

Requirements:
The ideal candidate should have a MSc Degree in Physics, Biomedical Engineering, Chemistry or Biotechnology. Laboratory experience in the field of drug delivery and nanomedicine is also expected together with high proficiency in spoken and written English.

References:
2. Di Francesco, M., Primavera, R., Romanelli, D., (...), Di Mascolo, D., Decuzzi, P. Hierarchical Microplates as Drug Depots with Controlled Geometry, Rigidity, and Therapeutic Efficacy 2018 ACS Applied Materials and Interfaces 10(11), pp. 9280-9289

Contacts:
Email: paolo.decuzzi@iit.it