ANNEX A-2

University of Genova – Istituto Italiano Tecnologia

Doctoral School on "*Life and Humanoid Technologies*"

Academic Year 2012-2013

Doctoral Course on

"*Nanosciences*"

Research Themes

30 positions available with scholarship

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INTRODUCTION TO RESEARCH THEMES

The Istituto Italiano di Tecnologia (IIT) is a research institution in Italy that is currently in an advanced startup phase. The fellowships assigned by IIT to the University of Genova are part of the start-up strategy of the Institute and have the specific goal of forming the first generation of IIT's research fellows.

Following the start of the Research Labs in the IIT's Headquarters in Genova Morego the PhD program supported by IIT is organized in a Doctoral School on Life and Humanoid Technologies" articulated in 4 courses. Each Course offers research topics proposed by the Research Directors and their senior collaborators. The candidates are asked to prepare a research project of their choice with explicit reference to the Theme proposed. The soundness of the project will be part of the evaluation process and will be considered preferential for the choice of the individual scientific theme that will be made jointly by the tutor and the candidate.

The Nanosciences Course is related to basic research and to research programs oriented to the comprehension of fundamental phenomena at the nanoscale and to the application of nanotechnologies to life sciences and to the development of new technologies, this is a challenge for the next twenty years. More specifically, nanobiotechologies have a broad field of application that goes from cells-to-chip and chip-tocells technologies to advanced characterization tools and imaging, from intelligent drug delivery to the development of artificial tissues and smart materials. So, the main research activities related to this course can be subdivided into the following main areas: 1. Nanochemistry that aims to advance the exploitation of nanostructures, fabricated by chemical approaches, as building blocks for engineered self assembly architectures across multiple length scales, from the molecular level up to the macroscopic world. The goal is related to the development of new strategies of nanostructure assembly able to create various types of nanoparticle architectures, to discover collective properties stemming from them, and to exploit such properties in a wide range of applications (for instance in energy-related applications and in medicine). The path to these architectures will exploit concepts that are amenable to large scale deposition and parallelization. The advanced fabrication of colloidal inorganic nanocrystals of a variety of materials will be one of the basic targets. These will be then surface-functionalized and assembled into both ordered and disordered superstructures onto substrates and in association various polymers, for preparing nanostructured films and surfaces, nanocomposites and nanocapsules. 2. Nanofabrication. Research is based on the utilization of advanced techniques of micro and nanomanufacturing to produce Micro Electric Mechanical Systems (MEMS), micro electrodes and scaffolds with dimensions comparable to cells, innovative devices for different applications. 3. Nanophysics research programs are focused to design, realize and utilize advanced methodologies and instrumentations within the framework of optical spectroscopy and microscopy, scanning force microscopy and optical nanoscopy, and are oriented to the study and characterization of nanostructured, biological and hybrid materials 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 we aim to integrate different design and knowledge levels from a 2D to a 4D (x, y, z, t). 4. Computer Vision research programs are focused on computational vision, Geometrical approach to 4D scene reconstruction, Sensors, Videosurvelliance (including tracking activity and behavioral analysis), Machine learning focused to image analysis and video sequences, Embedded Computer Vision.

The themes of the Doctoral Course on Nanosciences are structured as it follows:

1. Nanochemistry (Liberato Manna)
2. Nanostructures (Enzo Difabrizio)
3. Nanophysics (Alberto Diaspro)
4. Computer Vision (Vittorio Murino)

Each application must make specific reference to one of the research themes proposed.

NANOCHEMISTRY – LIBERATO MANNA NR. AVAILABLE POSITIONS: 7

Theme 1.1: Novel nanocrystal materials with enhanced light emission
Tutor: Iwan Moreels

Colloidal nanocrystals have proven to be a very versatile class of light-emitting materials. Depending on their composition, they can emit over the entire visible and near-infrared spectral range, and have high emission quantum efficiency. Nevertheless, most work has been performed on characterizing and employing spherical quantum dots, or at best quantum rods for photonics, and additionally, materials usually contain heavy metals (Pb, Cd), which is detrimental for practical applications. In this project, we will investigate novel nanocrystals for light-emitting applications. The aim is to engineer material composition, size and shape to achieve enhanced properties such as a fast PL lifetime, narrow emission linewidths and broad spectral tunability. Structural characterization of the synthesized nanocrystals will be done by techniques such as electron microscopy, X-ray diffraction and nuclear magnetic resonance spectroscopy. Additionally, there will be a strong emphasis on the exploration of the optical properties with absorption and temperature-dependent photoluminescent spectroscopy. The most suitable nanocrystals will finally be tested as gain materials for lasers. In collaboration with several other IIT-groups, the excited state carrier dynamics and amplified spontaneous emission will be studied, and the results will be benchmarked against the best currently available IIT nanocrystals, CdSe/CdS colloidal quantum dot-in-rods. The successful applicant should have a strong background in disciplines such chemistry and physics. Enthusiasm for tackling the multidisciplinary nature of the project is an asset.

For further details concerning the research project, please contact: iwan.moreels@iit.it

Theme 1.2: Engineered quantum dot architectures for enhanced charge transport and energy transfer
Tutor: Iwan Moreels

Over the past 10 years, tremendous progress has been made in synthesizing a wide variety of high-quality colloidal nanocrystals. For instance, metallic and heavily-doped semiconductor NCs showing a strong plasmonic behavior are now routinely prepared. We can also fabricate semiconductor NCs which are bright light emitters with excellent color purity, and by tailoring the ligand shell around the particles it has been demonstrated that close-packed layers of such NCs can be fabricated which show a good electrical conductivity. Many of these materials are already prepared by the IIT Nanochemistry department. In this project, we will use them to make tailored composite films consisting of different types of NCs. Specifically, plasmon/exciton hybrid materials will be investigated for improved charge transport in photovoltaic applications. Also, of great interest is the plasmonic enhancement of energy transfer rates between NCs for light emitting diodes, lasers or single photon emitters. The composites will be fabricated using a layer-by-layer assembly technique, or via colloidal crystallization of binary superlattices. Structural characterization will be done by X-ray diffraction and transmission electron microscopy. The majority of the project is focused on the charge and/or energy transport throughout the composite, which will be investigated using conductivity measurements and time-resolved photoluminescence spectroscopy, respectively. Experimental results will be coupled to a thorough modeling of the data, to enhance our understanding of the photophysical processes occurring in these exciting novel materials. The successful applicant should have a strong background in disciplines such chemistry and physics. Enthusiasm for tackling the multidisciplinary nature of the project is an asset.

For further details concerning the research project, please contact: iwan.moreels@iit.it

Theme 1.3: Transmission Electron Microscopy study of shape, structure and composition of nanomaterials for optolectronic and energy storage applications
Tutor: Rosaria Brescia, Andrea Falqui

The aim of this project it to study, via transmission electron microscopy (TEM) techniques, shape, structure and composition of various types of nanomaterials, even organized in self-assemblies, for optolectronic and energy storage applications. Special attention will be paid to the chemical analysis by Electron Energy Loss Spectroscopy (EELS) in TEM, even working in scanning mode (STEM), and by elemental mapping with energy filter (EFTEM). The analysis of the electron structure of the aforementioned materials will be focused on both low electron energy losses (such as plasmons and single particle excitations) and high electron energy losses (ionization edges and their fine structure) regions. Together with the experimental results, simulations of the EELS spectra will be carried out following one or more theoretical approaches.

For further details concerning the research project, please contact: rosaria.brescia@iit.it , andrea.falqui@iit.it

Theme 1.4: Advanced synthesis of nanoparticles for energy related applications
Tutor: Liberato Manna

The aims of this project are to develop scalable processes for the synthesis of nanoparticles into large batches that are required for energy related applications. Current laboratory syntheses of nanoparticles, especially those based on conventional flask-type reactors, are able to deliver only small amounts of particles, usually below one gram, and are plagued by low reproducibility and high synthesis costs. Various factors are involved here, like limitations of the size of the reactor, high costs of the chemicals involved, their toxicity, uncontrollable side effects of chemical impurities and others. A key activity will be the design of new synthesis schemes, for example based on continuous batch synthesis approaches, which will be able to deliver particles in amounts that are suitable for applications in catalysis, photovoltaics and energy storage. Emphasis will be put on processes based on low-toxicity, affordable chemicals. The final particles will need to undergo processes such as purification, eventual ligand exchange to make them stable in aqueous solutions (in order to prepare environmental friendly formulations), and will need to be characterized extensively. The successful candidate for this theme should have a strong background in disciplines such as Materials Science, Chemistry or Chemical Engineering.

For further details concerning the research project, please contact: liberato.manna@iit.it

Theme 1.5: Synthesis and assembly of nanoparticles and their exploitation in lithium ion batteries

Tutor: Chandramohan George

The aim of this research theme is to develop nanocrystals based composite materials for lithium ion battery applications. In lithium ion batteries, the most demanding task is to synthesize and characterize both positive and negative electrode materials in terms of size, shape and right stoichiometry. A wide range of transition metal oxides, hydrides, sulfides, phosphates, their composites and semi-metals conjunction will be explored. For this aim, colloidal, autoclave, microwave and vapor phase synthetic routes will be exploited. A focus is upon how the nanocrystal's shape anisotropy is expected to play a role in the battery's overall performance. Electrochemical studies will be followed at every level of the nanocrystal process, electrode preparation and upon the cell design and fabrication. To sum up, nanocrystal electrodes with high-rate capability, ease of processing, low-cost and environmentally benign, which are the bottom lines for the next generation lithium ion battery technology, will be the goals of this project. The successful candidate for this theme should have a strong background in disciplines such as Materials Science, Chemistry or Chemical Engineering.
For further details concerning the research project, please contact:
chandramohan.george@iit.it

Theme 1.6: Magnetic nanoparticles for cancer stem cell targeting
Tutor: Teresa Pellegrino

The aims of this theme are to develop colloidal magnetic nanocrystals as nano-platform for a combined cancer treatment, based on hyperthermia and drug release. The focus of the project will be on cancer stem cells (CSCs). To achieve these goals, different activities are foreseen: i) the identification of magnetic nanocrystals with high heat performance, synthesized by means of colloidal methods; ii) nanoparticle functionalization with pH and thermo-responsive coatings, for the controlled drug release upon application of intra (pH) or extracellular (temperature) stimuli; iii) stabilization of the nanoparticles in physiological conditions; iv) functionalization of the nanoparticle surface with cell targeting markers. These will include antibodies or cell pathways, such as "Notch and Wnt" signalling pathways, to address the nanoparticles towards CSCs; v) in vitro study on CSCs of the stimuli-triggered release of drug molecules; vi) study the effect of hyperthermia treatments operated by the magnetic nanoparticles on CSCs; vii) combined chemo and heat treatments as a function of drug and nanoparticle doses as well as frequency and magnetic field amplitude of the alternating magnetic field applied. The ideal applicant should have a background in cancer stem cell research with familiarity with chemistry subjects.

Conditions:
The research will be carried out in a stimulating, multidisciplinary environment promoting excellence in life science research, at the interface between biology, chemistry and medicine.

Excellent networking and training opportunities, including participation in summer schools, short research stays at other network partner organizations and attendance of international conferences.

This activity could be within a Marie Curie ITN network. If the European commission approves the project, the successful candidate will have the opportunity to apply for a Dual PhD together with the University of Regensburg, Germany, which will include a one year research stay at the University of Regensburg.

Requisites:
PhD candidate: research experience < 4 years at the time of the selection, being measured from the date when they obtained the degree which would formally entitle them to embark on a doctorate.

Mobility: Applicants can be nationals of any country but must not have resided or carried out their main activity in Italy for more than 12 months in the 3 years immediately prior to their recruitment. In case the candidate opts for a dual PhD degree, the mobility requisite applies also to Germany.

For further details concerning the research project, please contact: teresa.pellegrino@iit.it

Theme 1.7: Novel catalytic materials based on nanocomposites for water gas shift reaction and selective carbon monoxide oxidation
Tutor: Liberato Manna, Tania Montanari

The aim of this theme is to develop new catalysts for CO abatement in hydrogen-rich gases for fuel cells, produced through steam reforming of fossil fuels, alcohols or biomass. In polymer electrolyte fuel cells, due to their low operational temperature, the platinum catalyst is likely to be poisoned by carbon monoxide (CO), and the performance of the unit is degraded when CO is present in the reformed gas beyond a few ppm. In general, a CO removal unit is provided downstream a reforming unit which produces the reformed gas rich in hydrogen, and CO is selectively converted and removed through a series of reactions (water gas shift and, e.g., selective carbon monoxide oxidation) in order to obtain a CO concentration in the reformed gas <10 ppm. Typical catalysts for CO conversion are based on Cu-Zn, CeO_2-Au, and Fe_3O_4-Au. The aims here are to prepare new composite materials made of metal oxide nanocrystals/metal domains. These composite are expected to exhibit catalytic properties towards the water gas shift reaction and preferential CO oxidation. The steps involved will be: (a) Synthesis of various metal-metal oxide (MO) based nanostructures (by employing both non-hydrolytic and hydrolytic methods). (b) Assembly of these A-MO heterostructures to form composite materials. (c) Catalytic tests and catalyst characterization. The ideal applicant should have a background in chemistry or chemical engineering with familiarity with catalysis.

Conditions:

The research will be carried out in a stimulating, multidisciplinary environment promoting excellence in materials science, at the interface between chemistry, materials science and engineering.

Excellent networking and training opportunities, including participation in summer schools, short research stays at other network partner organizations and attendance of international conferences.

This activity could be within a Marie Curie ITN network. If the European commission approves the project, the successful candidate will have the opportunity to apply for a Dual PhD together with the University of Tarragona, Spain, which will include a one year research stay at the University of Tarragona.

Requisites:

PhD candidate: research experience < 4 years at the time of the selection, being measured from the date when they obtained the degree which would formally entitle them to embark on a doctorate.

Mobility: Applicants can be nationals of any country but must not have resided or carried out their main activity in Italy for more than 12 months in the 3 years immediately prior to their recruitment. In case the candidate opts for a dual PhD degree, the mobility requisite applies also to Spain.

For further details concerning the research project, please contact: liberato.manna@iit.it , tania.montanari@iit.it

NANOSTRUCTURES – ENZO DIFABRIZIO NR. AVAILABLE POSITIONS: 5

Theme 2.1: **Coupling excitons and plasmons.**
Tutors: Roman Krahne, Enzo Di Fabrizio

Colloidal nano crystals, and specifically core-shell nanorods, are an extremely versatile material for light emitters, and their excitonic properties have been well studied in our group. On the other hand, plasmonics has the capability to confine, guide and manipulate light in metal nano structures that are much smaller than the wavelength of light. The aim of this work is to design and fabricate hybrid semiconductor-metal nanostructures and to investigate their optoelectronic properties, with a focus on the coupling of excitons and plasmons. The candidate will fabricate the metal nanostructures in our clean room using optical, electron-beam, focused ion-beam lithography as well as atomic layer deposition and will functionalize these structures with colloidal nano crystals. The optical and electronic properties of the hybrid materials will be investigated.

Candidates should have a degree in physics, experience in clean room fabrication, and profound knowledge in the physics of condensed matter. Applications must contain the curriculum vitae and publications of the candidate, as well as a short outline (max 5 pages) of the candidates PhD research project.

For further details concerning the research project, please contact: roman.krahne@iit.it or enzo.difabrizio@iit.it

Theme 2.2: Advanced optical and electrical scanning probe spectroscopy
Tutors: Roman Krahne, Enzo Di Fabrizio

Combining scanning probe with Raman or optical emission spectroscopy can give deeper insight into material physics on the nanoscale. In our group we have several combined Raman and atomic force microscopy experimental setups that allow us to study optical and electrical properties of custom made tips and complex nanostructures. The aim of this work is to investigate locally the the properties of hybrid metal -semiconductor or inorganic-biomaterial systems and to design novel functional probe tips. The candidate
Candidates should have a degree in physics and have experience in scanning probe spectroscopy and/or clean room fabrication, as well as a solid background in condensed matter physics. Applications must contain the curriculum vitae and publications of the candidate, as well as a short outline (max 5 pages) of the candidates PhD research project.

For further details concerning the research project, please contact: roman.krahne@iit.it or enzo.difabrizio@iit.it

Theme 2.3: Plasmon adiabatic nanoscopy
Tutors: Francesco De Angelis, Enzo Di Fabrizio

In the last decade the fields of Raman/Infrared, and Atomic Force Microscopy experienced a huge but independent development. The potential progress derived by unifying these techniques is of primary importance for obtaining simultaneous and complementary information at level of single molecule study. The incredible proliferation of Nanofabrication technologies over the past decade is exactly what these fields needed to converge, allowing the development of a pioneering nanoscope. Our aim is to exploit the most recent progresses of Plasmonics and Nanotechnology to combine the mentioned techniques in one single tool, able to perform a comprehensive study of the molecular structure and interactions in native environment. The physical mechanism exploited is the adiabatic generation and compression of surface plasmon polaritons, used in combination with AFM technologies. The proposed Plasmon Adiabatic Nanoscope will be employed to study cell surface and membrane proteins in their native environment and label-free conditions. The use of this tool can be extended in the THz domain, that shows great promise to increase our knowledge on hydration-water properties - a crucial issue for understanding biomolecular function in a cellular context.This research theme strongly relies on nanofabrication advanced techniques and candidates should have a master in Physics, Chemistry or similar.

For further details concerning the research project, please contact: <u>francesco.deangelis@iit.it</u> or <u>enzo.difabrizio@iit.it</u>

References:

- F. De Angelis, et al., 3D adiabatic compression of surface plasmon polaritons for nano-mapping at 10 nm spatial resolution, Nature Nanotechnology, 5 (2010) 67-72.

Theme 2.4: Driving molecules for breaking the diffusion limit
Tutors: Francesco De Angelis, Enzo Di Fabrizio

The detection of few molecules from highly diluted solution is of extreme interest in different fields such as biomedicine, safety and eco pollution from rare and dangerous chemicals. Nanosensors cannot directly be used for detecting molecules dissolved in femto/atto molar solutions because of the so called "diffusion limit". In other words, they are diffusion limited and their detection performance becomes unpractical at those concentrations. To overcome this limitation, molecules of interest, initially dispersed in solution, can be guided toward the active area of the sensors exploiting superhydrophobic and superoleophobic surface. By combining plasmonic nanosensors with hydro/oleo-phobic surface unprecedented sensitivity levels can be reached, and the problem of detection of highly diluted sample can be faced radically.
This research theme strongly relies on nanofabrication advanced techniques and candidates should have a master in Physics, Chemistry or similar.

For further details concerning the research project, please contact: <u>francesco.deangelis@iit.it</u> or <u>enzo.difabrizio@iit.it</u>

References:

- F. De Angelis et al., Nature Nanotechnology, 2010, 5, 67-72.
- F. De Angelis et al., Nature Photonics, 2011, 5, 682-687.

Theme 2.5: Terahertz Metamaterial Sensors
Tutors: Luca Razzari, Enzo Di Fabrizio

Thin film sensing based on THz metamaterials (MTMs) has been growing recently as a promising modality for highly sensitive chemical and/or biological detection. Split-ring resonator (SRR) planar terahertz MTMs holds the ability to sense a thin dielectric layer. This sensing method is based on the changes in the capacitance of the SRRs: when a substance is added to the SRR-MTM structure, it changes its capacitance, which, in turn, shifts the resonant frequency, indicating the presence of the substance. In the next years, we plan to develop a novel generation of THz MTMs featuring nanoscale geometrical characteristics, such as nanogaps, which will allow higher sensitivities reducing the sensing area. The successful candidate will investigate new schemes and design novel THz MTM structures, making use of numerical software packages (based on techniques such as Finite Difference Time Domain, Finite Element Method, etc.), and will eventually participate in the experimental testing of the proposed devices.
Eligible candidates must have a Master degree in a relevant discipline (Physics, Physical Engineering, or equivalent) and some experience in numerical modeling of electromagnetic processes.

For further details concerning the research project, please contact: <u>luca.razzari@iit.it</u> or <u>enzo.difabrizio@iit.it</u>

Theme 2.6: Vibrational spectroscopic analysis of protein/peptide fibrillation
Tutors: Gobind Das, Enzo Di Fabrizio

The study on protein fibrillation has grown up in recent years due to the root cause of various diseases such as alzheimer, diabetes, cardiac arrest, etc.. The fibrillation is a process, wherein, the protein misfolding/nucleation occurs, causing a remarkable increase in -sheet conformation. In addition to the concentration, solvent pH and temperature, the time lag in nucleation process and, subsequently, protein fibrillation can be varied by addition of polymer, nanoparticles, etc.. In this work, a nanostructured substrate (1) will be used as a sample holder for the evaporation of excess water content and thereafter the free standing fibril protein can be taken out from the substrate surface to further study by means of -Fourier Transform Infra-red (FTIR) absorption and -Raman scattering techniques. These techniques can provide the in-depth understanding of secondary structure conformation via chemical vibrational bands (2).

For this project, the candidates should have a master degree in physics, chemistry, biotechnology or equivalent in engineering. A prior knowledge of matlab/matematica and hand-on experience with experimental techniques (Raman and FTIR) will be an advantage.

For further details concerning the research project, please contact: gobind.das@iit.it or enzo.difabrizio@iit.it

References:

- A. Accardo et al., In situ X-ray scattering studies of protein solution droplets drying on micro- and nanopatterned superhydrophobic PMMA surfaces, Langmuir, 26, (2010), 15057-15064.
- G. Das et al, Nano-patterned SERS substrate: application for protein analysis vs. temperature, Biosensors and Bioelectronics, 24, (2009), 1693-1699.

Theme 2.7: High-resolution chemical mapping using tip-enhanced Raman spectroscopy
Tutors: Gobind Das, Enzo Di Fabrizio

Near-field Raman spectroscopy facilitates the recognition of molecular vibrations in the scale down to few nanometers, much below than the diffraction limit of the light. The motive of this work is to couple the two techniques: 1) the sensitivity and rich chemical information of SERS and 2) the excellent spatial resolution of metal-coated scanning probe microscopy tip, in order to gain the capability for single molecule detection. There could be wide analytical applications of our combined-system in various fields from condensed matter to biomedicine. The Ph.D. student will work on SERS substrate fabrication and, thereafter, to couple the device for TERS measurements.
Candidates should have a degree in physics or engineering, experience in Raman spectroscopy/atomic force microscopy. Having experience in clean room fabrication will be an additional advantage.

For further details concerning the research project, please contact: gobind.das@iit.it or enzo.difabrizio@iit.it

Theme 2.8: Development of next generation materials for rechargeable Lithium Batteries.
Tutors: Claudio Capiglia, Remo Proietti, Enzo Di Fabrizio

To apply for the Ph.D. degree applicants should meet the requirements for the M.S., and possess an M.S. degree in Materials Science and Engineering or equivalent, or an M.S. in Electrochemistry.
The candidate will be involved in both the chemical-physical (SEM, TEM, XRD, DSC) and electrochemical (CV, Impedance) synthesis and characterizations of a new generation of anodes/cathodes materials.   Furthermore, he/she will be asked to face the fabrication of these devices and to test them (charge/discharge) when integrated in electrochemical cells.
The Application include a statement of purpose. This statement should be precise and brief, and state your academic and research interests. Describe exactly what you wish to study at the IIT Nanostructure Department, state what branch of Materials Science and Engineering interests you. Candidate with research interest in both academia and industrial research are advantaged.

For further details concerning the research project, please contact: Claudio.capiglia@iit.it or remo.proietti@iit.it, enzo.difabrizio@iit.it

Theme 2.9: Theoretical/numerical investigation and design of plasmonic nanoantennas.
Tutors: Remo Proietti, Enzo Di Fabrizio

PhD activity will consist on the fabrication by means of advanced lithographic techniques (i.e. EBL, FIB, SPM nanolithography) of size-dependent plasmonic nanostructures and engineered scanning probe tips, with the aim of investigate plasmonic excitations in noble metals nano-features. The study will rely on state of the art scanning probe techniques such as cryogenic STM-STS, high resolution AFM, conductive AFM and EFM both in UHV and room conditions in order to evaluate electrical coupling between incident light, structured samples and engineered tips. The candidate will acquire a good clean room expertise combined with electrical nanoimaging for advanced light harvesting techniques, working in a multidisciplinary environment across nanofabrication and nanophysics. Candidates should have a M.D. in Physics, Material Science or Engineering, better if accomplished with a good background in SPM and/or electron beam lithography techniques.

For further details concerning the research project, please contact: remo.proietti@iit.it or enzo.difabrizio@iit.it

Theme 2.10: Design of photonic crystal based plasmonic devices for ultrafast spectroscopy
Tutors: Remo Proietti, Enzo Di Fabrizio

To apply for the Ph.D. degree applicants should meet the requirements for   the M.S., and possess an M.S. degree in Physics or equivalent.
The candidate will investigate the effect played by photonic crystals in the modification of the lifetime of plasmonic systems. In particular, the final goal is the design of a device capable of sensibly increasing the lifetime of surface plasmon polaritons. In fact, this device will be fabricated by the team for further experimental study at the femto-second scale.
Candidate with interest in experimental optics are advantaged

For further details concerning the research project, please contact: remo.proietti@iit.it or

enzo.difabrizio@iit.it

NANOPHYSICS – ALBERTO DIASPRO NR.AVAILABLE POSITIONS: 12

Theme 3.1: Two-photon STED Optical Nanoscopy towards label-free super-resolution microscopy.
Tutors: Alberto Diaspro, Paolo Bianchini

A recognized advantage of optical microscopy lies in the fact that allows non-invasive three-dimensional (3D) imaging of live cells at the submicron scale with high specificity. The advent of the visible fluorescent proteins and of a myriad of fluorescent tags pushed fluorescence microscopy to become the most popular imaging tool in cell biology. The confocal and multiphoton versions of fluorescence microscopy reinforce this condition. However, like any other standard imaging system relying on focused light, all these microscopes are limited in spatial resolution because the smallest possible spot size is imposed by diffraction. Several approaches aimed at overcoming the diffraction limit. Stimulated Emission Depletion (STED) microscopy is one of the most promising Optical Nanoscopy approaches allowing an ultimate resolution of 7.6 nm in the optical regime. In STED microscopy, fluorescence emanating from the periphery of the focused excitation beam is suppressed by a second properly shaped beam that depletes the excited state population through stimulated emission. This effectively narrows fluorescent molecule signature, the point spread function (PSF) of the microscope, to permit super-resolved images to be acquired. The Optical Nanoscopy theme is related to the development of an original class of two-photon excitation–stimulated emission depletion (2PE-STED) optical microscope1. There will be the opportunity to perform super-resolved fluorescence imaging, exciting and stimulating the emission of a fluorophore by means of a single wavelength. This imaging technique will be extended to the bioimaging of thick samples at nanoscale resolution in all the three dimensions, for key applications to tracking of molecular events in living cells towards the study of degenerative processes like neuro-diseases, tumor progression and nanoparticle toxic effects on biological systems.

Reference:

Bianchini, P., B. Harke, S. Galiani, G. Vicidomini, and A. Diaspro. 2012. Single-wavelength two-photon excitation-stimulated emission depletion (SW2PE-STED) superresolution imaging. Proceedings of the National Academy of Sciences. 109: 6390–6393.
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For further details concerning the research project, please contact: paolo.bianchini@iit.it alberto.diaspro@iit.it

Theme 3.2: High-throughput label free methods in non-linear optical microscopy towards tissue engineering.
Tutor: Paolo Bianchini, Alberto Diaspro

New approaches to capture signals from unlabeled biological molecules may finally fulfill the promise of practical label-free microscopy with molecular specificity. An important aim of tissue engineering is to provide a three-dimensional structure mimicking some of the extracellular matrix features, and it remains unclear whether the pattern and the molecular structure of the newly tissue might be different and labeling may perturb the function of biomolecules, the use of label-free approaches results particularly powerful. Label-free microscopy methods rely on a variety of different photo-physical processes to generate light signals from biological macromolecules, among them we focus on non linear interactions like the ones related to two-photon excitation microscopy and second harmonic generation (SHG) microscopy1. Two-photon excitation (TPE) microscopy can detect some prevalent autofluorescent molecules and SHG methods allow distinguishing fibrillar structures. We aim to use TPE and backward/forward SHG for the comprehension of scaffold geometry dependent differences in collagen fiber concentration and organization within newly formed tissues in unloading vs. loading conditions. The most intriguing concept is obtaining materials able to mimic a specific eventually pre-existing microenvironment, thus priming the natural processes of bone regeneration driven by cells. Within this framework, it is still unclear, whether the pattern and the molecular structure of the newly formed tissues might grow in different ways, based on the chemico-physical cues, for example, given by scaffold design. TPE and SHG approaches will be focused to elucidate such mechanisms, but both scaffolds and real tissues have a size that exceed the field of view of high resolution nonlinear microscope. Thus we aim to develop a new method that allows a fast collection and analysis of many 3D stacks from several complete pieces in order to gather information from the micro to the macro scales.

Reference:

Bianchini, P.,and A. Diaspro. 2008. Three-dimensional (3D) backward and forward second harmonic generation (SHG) microscopy of biological tissues. J. Biophoton. 1: 443–450.

For further details concerning the research project, please contact: paolo.bianchini@iit.it alberto.diaspro@iit.it

Theme 3.3: Deformation and fracture behavior of nanoparticle superstructures
Tutor: Luca Ceseracciu

Colloidal nanocrystals (NCs) form a family of highly advanced building blocks suitable for large scale assembly of high-complexity superstructures. Among the structures that can be produced, self-assembled superlattices are especially novel and promising for a bottom-up approach to microdevices, whose properties can be effectively controlled by tailoring their size, shape, composition and surface functionalization.
It is known that deformation and fracture mechanisms at the nanoscale are different from the macroscopic models. The way such properties reflect on the behavior of larger structures is unknown and expected to be highly non linear. Mechanical properties will be characterized by nanoscale testing under several loading conditions; quasi-static, dynamic to extract viscous properties, impact. Testing will be accompanied by modeling, both analytical and numerical.
Requirements: The successful candidate will have experience in mechanical characterization, especially nanoindentation, and in Finite Element Analysis.

For further details concerning the research project, please contact:
luca.ceseracciu@iit.it@iit.it

Theme 3.4: Biomechanics of bioactive materials for tissue engineering applications
Tutors: Luca Ceseracciu and Silvia Scaglione

In the past years, great progress has been made in understanding the essential requirements that have to be satisfied by synthetic/natural materials to be proposed as scaffolds for tissue engineering applications. An essential task that needs to be addressed in the realization of biomimetic scaffolds is the coupling of structural properties, such as porosity and mechanical strength, and proper biochemical-topological cues provided by the scaffolds, in order to guide a specific and selective cellular differentiation in vitro and tissue formation in vivo. This is especially challenging in scaffolds designed to support more than one tissue, with specific requirements in both aspects, such as osteochondral scaffolds. To overcome these limitations, novel three-dimensional bioactive biomaterials are needed, capable of sustaining and guiding respectively bone and cartilage tissue generation, according to the stimuli decoded by the cells. Within this project, we will pursue the integration of bio-hybrid synthetic techniques, nanotechnologies and advanced material processing technologies to obtain three-dimensional scaffolds able to guide and control tissue growth, differentiation and proliferation. Special attention will be devoted to the characterization and optimization of the mechanical response of the scaffolds.
Requirements: Potential candidates should have basic background in one or more of the following fields: bioengineering, materials science, physics, chemistry, biomechanics.

For further details concerning the research project, please contact:
luca.ceseracciu@iit.it@iit.it

Theme 3.5: Interfacing single layer graphene with biological cells
Tutors: Silvia Dante, Bruno Torre, Alberto Diaspro

The seek for biocompatible functional material is a key issue for many bioengineering application, such as biosensors, neuron-electrode interface and biodiagnostic. Among these recent developed materials such as graphene and graphene oxide have recently attracted much attention because easily processable and virtually transferrable on every substrate with high conductivity and transparency. Moreover it has been recently demonstrated that they are biocompatible after simple treatments. Therefore it is an ideal candidate for novel biomaterials. In this frame we propose a PhD activity about the study of the inteface between graphene and/or graphene oxide and cells/neurons, with particular focus on cell adhesion, proliferation and signalling. The exploitation of the optical and electronic properties of graphene for the development of graphene-based biocellular devices will be pursued.
Candidates should have a M.D. Biotechnology, Bioengineering, Chemistry, Physics, Material Science.

For further details concerning the research project please contact: silvia.dante@iit.it

Theme 3.6: Atomic Force Microscopy (AFM) applications in life sciences and nanomedicine.
Tutor: Claudio Canale

AFM has become a powerful tool in biomedical research thanks to its capability in terms of visualization, probing and manipulation of biological samples. In the last years AFM applications on cells opened new insight in cells biophysics, improving the knowledge on pathological mechanisms. Changes in cell stiffness were demonstrated to be related to some kind of cancer diseases (Nature Nanotech., (2007) **2**:780-783), while the overexpression of proteins of the nuclear lamina can increase the rigidity of the nucleus itself (Biophys.J. (2009) **96**:4319-4325). The adhesion properties of cells can be also affected by pathological dysfunctions. Different biophysical parameters of cells will be tested using advanced AFM techniques; the work will be focused on the study of cancer cells and cells from patients affected by neurodegenerative diseases.
The interaction between cells and pathogenic agents will be studied using the same techniques, as well as the effect of drugs on the recovery of cell toward a non-pathological phenotype.
Model system will be used in order to investigate phenomena related to pathologies at the molecular level.

For further details concerning the research project, please contact: claudio.canale@iit.it

Theme 3.7: APA coating of dental & orthopedic implants
Tutors: Marco Salerno

This project aims to use anodic porous alumina (APA) as a coating agent for dental and eventually orthopedic implants in order to enhance osteointegration and replace the original tissue functionality. APA has already been tested in a number of studies as a substrate for cell attachment and proliferation [6,7], or as a membrane for controlled drugs diffusion [1,3] We would like to use APA as a coating of bulk materials used for implant devices (typically Titanium and its alloys). The controlled APA porosity should be put at work for both morphological integration with the surrounding bone tissue, and additionally for use as a reservoir for delivery of functional agents such as growth factors or antibacterial molecules or nanoparticles. In turn, the possible toxic effect due to release of Al3+ ions should be controlled.
Therefore, first the manufacturing of an APA coating of appropriate coverage, stability and thickness on a 3D implant body should be engineered, overcoming issues related to the fragility of the oxide and its possible delamination from the substrate. Second, methods to load drugs into the APA structure and tune their release will investigated. Finally, studies of cell cultures on the implant modified surfaces will be performed, mainly with osteoblasts and, eventually, with fibroblasts, representing both bone and gingival tissue models, respectively.
The project is organized in 3 phases of advancement, roughly corresponding to the 3 PhD studentship years.

For further details concerning the research project, please contact: marco.salerno@iit.it or fernando.brandi@iit.it

Theme 3.8: Evaluation of structural, optical and electronic properties single layer graphene and stacked multilayer graphene, as well as its interaction with adatoms, macromolecules and nanoparticles at atomic scale by mean of AFM, STM-STS and related techniques, for sensing applications
Tutors: Bruno Torre

PhD activity will consist on the study of graphene based nanostructures and the dependence of their electronics and optical properties on the interaction with gas molecules, macromolecules and nanoparticles for sensing devices applications, by means of atomically resolved techniques. The main activity will rely on experimental techniques such as cryogenic STM-STS, high resolution AFM, conductive AFM and Kelvin probe both in UHV and room conditions; spectroscopies, optical microscopy, SEM and TEM related techniques will be available for complementary analysis.
Candidates should have a M.D. in Physics, Material Science or Chemistry, better if accomplished with a good background in SPM related techniques; knowledge in UHV technology and cryogenics are preferential, but not mandatory.
For further details concerning the research project, please contact: bruno.torre@iit.it

Theme 3.9 Development and characterization of magnetic and conducting polymer composites
Tutors: Despina Fragouli, Athanassia Athanassiou

Applications are invited for a PhD position in the development and characterization of magnetic or conductive polymer-based nanocomposites. The candidate must have a Bachelor's Degree in one of the following areas: Physics, Material Science, Chemistry, or Engineering with a priority order as indicated. Magnetic and conducting polymer nanocomposites are smart and functional materials with physical properties that can be instantaneously and reversibly controlled by an external stimulus. They possess a synergistic performance of the embedded particles and polymer matrix combined together, preserving the properties of the individual components, but exhibiting characteristics that would not be possible otherwise. MCPCs have numerous potential applications, such as sensing, actuation and vibration absorbing technology. The objectives of the project will be the development of a fabrication technology for magnetic and conducting polymer nanocomposites based on various polymer matrices and particles with a range of physical properties and morphologies, including particle surface modification, components mixing, polymer curing and anisotropy controlling. The polymer matrices may be conductive or not and the nanoparticles may be superparamagnetic/ferromagnetic or conductive, or novel structured particles. The mixing, and solid sample formation will be done both using the final form of the polymer upon drop casting or spin coating, or starting from the monomer forms and curing using laser light or heating. The characterization of the multi-scale structures will be done with various microscopic techniques, together with the characterization of the physical properties such as thermo-mechanical, magnetic, conductive, using simple or sophisticated instrumentation the IIT provides. The final composites will be used for the development of biosensors, actuators or other novel devices. Previous experience on magnetic or polymeric materials will be highly appreciated.
For further details concerning the research project, please contact: despina.fragouli@iit.it or athanassia.athanassiou@iit.it

Theme 3.10: Title: Toward low-intensity STED microscopy
Tutors: Giuseppe Vicidomini, Alberto Diaspro

Stimulated emission depletion (STED) microscopy was the pioneer of far-field (lens-based) fluorescence nanoscopy. It was the first viable physical concepts that "broke" the diffraction barrier in light microscopy: spatial resolution can be increased (at least conceptually) to the molecular scale or even beyond. In a nutshell, in the STED microscope the diffraction limited excitation focus is overlaid with a red-shifted STED beam featuring a zero intensity point. The STED beam depletes the molecular fluorescent state everywhere within the focal region by means of stimulated emission, except at the zero intensity point and its proximity, thereby confining the spatial extent of the effective fluorescence volume.
Among the major steps in the development of STED microscopy, the demonstration of the use continuous wave lasers (CW-STED) was certainly contributing the most to a wide dissemination of the method due to the affordability and elegant simplicity of its implementation. Nevertheless, CW-STED was so far not reaching the same spatial resolution as pulsed-lasers STED configurations. A recent investigation on the time-course of the fluorescence emission probability in CW-STED has revealed the benefit of using gated fluorescence detection (gSTED) to improve further the resolution of CW-STED and/or to reduce the STED intensity in the sample for a given resolution. In addition, the reduction of laser intensity decreases the stress on the samples, especially on the stability of the dye and on cellular components when performing live-cell imaging.
The aim of this research project is to develop and investigate new methods for further reducing the laser intensity demand for gSTED. The candidate will be responsible not only for developing and optimizing the optical architecture of a gSTED microscope, but also for developing and implementing dedicated computational approaches for data analysis and processing.
We are looking for talented, independent and enthusiastic candidates with strong mathematical (programming) skills along with an interest also in experimental work. He/she must have an excellent knowledge of written and spoken English and a top 20% ranking during his/her BSc and MSc.Previous experience with fluorescence microscopy and image processing is an advantage, but not necessary. **For further details concerning the research project, please contact: giuseppe.vicidomini@iit.it, or alberto.diaspro@iit.it**

Theme 3.11: Excimer laser-based mask projection stereolithography: a production and characterization of 3D microstructures for applications in biotechnology
Tutor: Fernando Brandi

The Laser Micromachining Team has recently developed a novel method to fabricate 3D polymeric scaffolds with controlled microarchitecture by a layer-by-layer phorocrosslinking technique [1,2]. This innovative technique enables to speed up the production efficiency due to the use of high power UV laser.

The present project aims at the fabrication of 3D biocompatible scaffolds for tissue engineering applications.   The multidisciplinary IIT environment gives the possibility to further investigate a variety of applications of the produced microstructures, from microfluidics to nanocomposite production.

The applicant should hold a degree in experimental physics, chemistry, or engineering, preferentially with a solid background on laser materials processing.

References:
[1] F. Brandi et. al., J. Micormech. Microeng. 21 (2011) 054007
[2] S. Beke et.al., J. R. Soc. Interface, 2012, doi: 10.1098/rsif.2012.0300

For further information concerning the research project, please contact Dr. Fernando Brandi
fernando.brandi@iit.it

Theme 3.12: Excimer laser-based mask projection stereolithography: a production and characterization of 3D microstructures for applications in biotechnology
Tutor: Fernando Brandi

Laser micromachining is a powerful, yet versatile, technique used to fabricate micrometer size structures, and is finding more and more applications in micro/nano-tecnology.

This project will focus on the use of laser based technique for the efficient micro-machining of hard materials (like silicon and diamonds), polymers,   as   well as innovative materials like single layer Graphene for the fabrication of innovative bio-chip. Activities include, but are not limited to: laser micromachining of synthetic diamond; laser micromachining of thin polymeric membranes for 3D cell culture bio-chip; single layer Graphene laser micropatterning for controlled neuronal network growth. The produces parts will be fully characterized using the wealth of apparatus available in the Nano-Biotechnology Facility (electron microscopy, micro-Raman, confocal microscopy, AFM and nano-indentation).

The applicant should hold a degree in experimental physics or engineering.

For further information concerning the research project, please contact Dr. Fernando Brandi
fernando.brandi@iit.it

Theme 3.13: Surface Wetting Properties of micro/nanostructured composites
Tutors: Ilker Bayer, Athanassia Athanassiou

Applications are invited for a PhD position in the development of polymeric surfaces with controlled morphological features in the micro and nanoscale. The candidate must have a Bachelor's Degree in one of the following areas: Physics, Material Science, Chemistry, Chemical Engineering, or Biotechnology.

Different techniques top down and bottom up, such as soft molding, spraying, electrospinning, ablation, self-assembly, will be developed and used for changing the morphological characteristics of polymeric surfaces. The aim will be the fine control of their wetting properties, such as wettability and liquid adhesion. Additional surface properties including anti-scratch, anti-fingerprint and anti-icing will also be studied. The effect of the chemistry of the used materials, of their mechanical properties, and of the different-length scales of the induced roughness on the surface properties will be examined. The study will be performed on polymeric coatings and on free standing polymeric substrates in order to point towards diverse applications, such as protective coatings for furniture, buildings etc., as well as cells growth, microfluidics etc.

For further details concerning the research project, please contact: ilker.bayer@iit.it   or athanassia.athanassiou@iit.it

Theme 3.14 Development of Novel Natural Polymer Nanocomposites
Tutor: Athanassia Athanassiou

Applications are invited for a PhD position in the development of novel materials based on natural polymers enriched with organic or inorganic nanofillers. The candidate must have a Bachelor's Degree in one of the following areas: Chemistry, Material Science, Chemical Engineering, Biotechnology, or Physics.

Different natural polysaccharides (cellulose, chitosan, alginates, starch, gums) will be used after their appropriate modification with physicochemical methods in order to produce films or coatings for applications such as food packaging, wound healing patches, edible films etc. The proper incorporation of selected NPs, organic or inorganic, or a combination of both will be used for improving thermal, mechanical, antibacterial, antioxidant, gas barrier, water impermeability, and optical properties of such materials. The candidate will be responsible for the development and characterization of the natural polymeric composites using a variety of techniques provided at IIT such as optical, and scanning probe microscopic techniques, thermo-mechanical tests, spectroscopic techniques, wettability measurement methods, etc. Previous experience with natural polysaccharides will be highly appreciated.

For further details concerning the research project, please contact:
athanassia.athanassiou@iit.it

Theme 3.15: Development of Polymer Nanocomposites with in-situ Synthesis of Nanoparticles for Biological Applications
Tutors: Elisa Mele, Athanassia Athanassiou

Applications are invited for a PhD position in the development of polymer nanocomposites, based on the in-situ synthesis of nanoparticles (NPs), and their application in biological studies. The candidate must have a Bachelor's Degree in one of the following areas: Physics, Material Science, Biotechnology, Chemistry, or Engineering with a priority order as indicated.

The synthesis of inorganic NPs by using a polymer matrix as chemical reactor has led to the development of a novel class of nanocomposite materials, where the nucleation, growth and organization of the functional particles of interest is controlled by the polymeric network, also including macromolecules of biological origin. A wide variety of NPs can be in-situ synthesized, ranging from gold, silver, platinum, to magnetic iron oxides. This class of polymer nanocomposites have attracted a great deal of attention because of their application in biosensors, enzyme reactors, immunoassays and biochemical analysis.

The research activity of the project will be mainly focused on the investigation of the in-situ synthesis of NPs within synthetic and natural polymers that include elastomers and polysaccharides. Particularly, the chemical-physical mechanism at the basis of the NPs formations will be investigated, and properly controlled in order to create nanocomposites with specific properties. The produced matrix will be employed for the realization of systems (that could be based on films, microfibers and microdroplets) with advanced functionalities. The characterization of the final structures will be carried out by means of microscopic, mechanical, and chemical analysis. Finally, the novel material will be employed in the realization of devices for the immobilization of antigen, enzymes and other biomolecules in microreactors, sensors, and immunoassays. Previous experience on composite or polymeric materials will be highly appreciated.

For further details concerning the research project, please contact: elisa.mele@iit.it or
athanassia.athanassiou@iit.it

Theme 3.16: Laser Generated Nanoparticle in Liquid for Biomedical applications
Tutor: Romuald intartaglia

Different nanoparticle materials are already used for a variety of applications such as bio-imaging, antiseptic metal ion release, cancer treatment, UV-protection, photo-catalytic effects, scratch-resistance and corrosion protection. But the availability of nanoparticles with high purity is still lacking in particular for biomedical applications. Our line research is to develop the laser ablation technique in liquid environment for the direct synthesis of nanomaterials - metallic (Au,Ag,Ni,Fe,..) and semiconducting (Si,Ge,.)-. Biocompatibilty improvement of these nanoparticles are predicted due to their restricted surface contamination, since the synthesis is carried out in water or in a solution of biocompatible ligand. The synthesis of Colloidal nanoparticles will be initially investigated, changing the laser parameters and liquid environment. These obtained nanoparticles are then characterized from point of view of their structural, electronic and optical properties in order to retrieve a clear picture of their basic physical properties. Optical and structural characterization of nanocrystals will be carried out by means of spectroscopic techniques such as Absorption, Fluorescence and Fourier transform infrared spectroscopy (FTIR) spectroscopy and Transmission Electronic Microscopy (TEM).
For further details concerning the research project, please contact: romuald.intartaglia@iit.it

Theme 3.17: New applications in optical nanoscopy using high resolution concepts like RESOLFT or STED.
Tutors: Benjamin Harke, Alberto Diaspro

Circumventing the classical resolution limit in optical microscopy has been one of the most significant fields of research during the last years.   Especially, improving the resolution of a fluorescence microscope has been of major interest since this imaging technique has become a standard for biological applications. One of the most promising ways to enhance the resolution of this optical imaging tool was realized in a STED microscope. Remarkable is that in this nanoscope no theoretical limit confines the resolution(1). This is mainly given by the efficiency of the switching process between the fluorescent and the non-fluorescent state. The straightforward implementation of the STED technique to an existing confocal microscope makes it very flexible towards new outstanding combinations with other high resolution instruments. In order to reach highest resolution, a detailed understanding of the switching mechanism is mandatory especially when extending the idea of STED to more general switching processes. For biological applications, the switching of fluorescent proteins gave recently remarkable results. In the field of lithographic fabrication techniques, the diffraction limit of photo-polymerization has been circumvent by selectively inhibiting the polymerization process. Building up or modifying an appropriate optical setup and accomplish spectroscopic measurements in the molecular regime will be part of the PhD project. Additionally, improving this technique in terms of more convenient laser systems or phase patterns for generating the switching beam will be included. Excellent equipment for studying physical and chemical properties of interest will be available.

Reference:

Harke, B., J. Keller, C.K. Ullal, V. Westphal, A. Schönle, et al. 2008. Resolution scaling in STED microscopy. Opt. Express. 16: 4154–4162.

For further details concerning the research project, please contact: benjamin.harke@iit.it   or alberto.diaspro@iit.it.

Theme 3.18: Super-resolution microscopy within a light sheet three-dimensional approach.
Tutors: Francesca Cella Zanacchi, Alberto Diaspro

In the last few years super-resolution microscopy based on single molecule localization became a powerful tool for imaging biological structures at the molecular level. Super-resolution methods belonging to this family are mainly based on the ability to image sparse events within the sample of interest - biological or nanostructured materials - thus enabling the possibility of localizing tagged molecules with a nanometer precision (10-30 nm). On the other side, two photon excitation (TPE), implemented into a light sheet based configuration, can be exploited to improve imaging capabilities of thick biological samples. The combination of two-photon light sheet illumination microscopy and super-resolution imaging techniques based on individual molecule localization (IML-SPIM) represents an innovative optical architecture able to provide an extended imaging depth capability and 3D super-resolution imaging of thick living samples.
The aim of the proposed project is focused on the implementation of a custom super-resolution imaging system based on TPE light sheet illumination. Within the phD project the candidate will have the opportunity to gain experience on super-resolution imaging techniques and light sheet microscopy, working both on the design and implementation of the optical system and its application. The imaging system will be applied to biological problems within the neuroscience context, such as brain and retinal imaging.
We look for motivated candidates with Physics\Engineer background interested in optical microscopy and super-resolution imaging techniques.

Reference:

Cella Zanacchi F, Lavagnino Z., Perrone Donnorso M., Del Bue A., Furia L., Faretta M., Diaspro A. (2011) Live-cell 3D superresolution imaging in thick biological samples.
 Nature Methods. 8(12): 1047 – 1049

For further details concerning the research project, please contact: francesca.cella@iit.it or alberto.diaspro@iit.it

Theme 3.19: Advanced selective plane illumination microscopy (SPIM).
Tutors: Francesca Cella Zanacchi, Alberto Diaspro

Light-sheet fluorescence based techniques have been found particularly useful in developmental biology applications since they provide the capability to perform fast imaging of living samples reducing photobleaching effects. In particular, selective plane illumination (SPIM), implemented in both linear and non-linear excitation regime, provides optical sectioning capability due to the planar excitation scheme, representing a useful tool for biological investigations of thick biological samples.
The proposed project will be focused on the development of an innovative light sheet based imaging architecture with improved axial resolution and enhanced optical sectioning capabilities. The basic idea relies on the possibility to exploit the stimulated emission depletion principle (STED) and Bessel beam generation in order to reduce the thickness of the light sheet, thus improving the imaging performances of the system. Within the proposed phD project the candidate will work on the design, development and optimization of the optical architecture oriented to super-resolution imaging of biological samples of interest.
We look for candidates with Physics\Engineer background interested in optical microscopy and super-resolution imaging techniques. Candidates with background in biophysics or optical physics are invited to apply for this position.

Reference:

Cella Zanacchi F, Lavagnino Z., Perrone Donnorso M., Del Bue A., Furia L., Faretta M., Diaspro A. (2011) Live-cell 3D superresolution imaging in thick biological samples.
 Nature Methods. 8(12): 1047 – 1049

For further details concerning the research project, please contact: francesca.cella@iit.it or alberto.diaspro@iit.it

Theme 3.20: Experimental determination of spatial correlation in the dynamics of systems undergoing a glass transition
Tutors: Paolo Bianchini, Ranieri Bizzarri, Donatella Bulone

Although the phenomenon of glass transition has been known from millennia, the molecular events that originate the dynamic arrest are still unclear. New interest toward this topic was added by the observation that a common phenomenology accompanies different processes such as vitrification, jamming of granular matter or sol-gel transition. Physically the slowing down reflects the progressive confinement of a given particle by a cage formed by its neighbors. Different experimental and theoretical studies had shown that the approaching to transition is characterized by the appearance of dynamic heterogeneities. Actually some regions of the sample exhibit faster dynamics than the rest and particles within these regions move cooperatively. The experimental determination of this correlation length and its dependence on the critical parameter that regulates the distance from the transition treshold, is of uttermost importance in materials science applied to technology and biology, aiming at the fine tailoring of generated materials.

In this research project we propose to apply the high spatial and temporal resolution of optical microscopy to provide a comprehensive understanding of glass transition processes in selected polymeric materials with (bio)technological relevance. In more details, methods to monitor the progressive "caging" of polymeric chains will be set up by taking advantage of the following techniques:

- Phase contrast microscopy, to visualize changes in refraction index at submicron level.
- Fluorescence correlation spectroscopy, to provide spatial and temporal correlation between diffusion phenomena
- Single molecule tracking microscopy
- Fluorescence lifetime imaging (FLIM) by using novel environmentally-sensitive fluorescent dyes (polarity, viscosity, and aggregation sensors)

This research will be interfaced with existing research projects at IIT and CNR-Institute of Biophysics (Palermo and Pisa) and will take advantage of state-of-art microscopy instrumentation and cutting-edge experience of scientific tutors.

For further details concerning the research project, please contact: paolo.bianchini@iit.it , donatella.bulone@pa.ibf.cnr.it or r.bizzarri@sns.it.

COMPUTER VISION – VITTORIO MURINO NR.AVAILABLE POSITIONS: 6

Theme 4.1: Computer vision for behavioral analysis and activity recognition
Tutor: Vittorio Murino

Study and development of techniques and systems for the analysis of behaviours, actions, expressions/emotions, and social signals in general, referred to both single persons and groups. In this context, methods for tracking, recognition, and classification of persons and objects starting from images and/or sequences acquired from cameras distributed in the environment in different sparse locations, and from other types of sensors (e.g., microphones) will be considered. The main goal is to exploit hints and findings coming from social sciences to capture and model human behaviour. Computer vision and machine learning constitute the focus of this research.
For further details concerning the research project, please contact: vittorio.murino@iit.it

Theme 4.2: Part-based human body modeling
Tutor: Marco Cristani

To recognize and interpret human nonverbal behavior it is fundamental to try to identify the subjects involved, especially in the wild, that is in real situation. To this end, part-based human body modeling is a mandatory task aimed at extracting from images the different components of the human body, like head, torso, arms, legs, etc., so as to estimate posture, gesture and gaze, all social cues widely known as useful hints to classify behavior and recognize situations. Further, real time tracking of body parts is equally important to increase such recognition performances, possibly adding prediction functionalities to these algorithms. Computer vision and machine learning methodologies are the main subjects of this study.
For further details concerning the research project, please contact: marco.cristani@iit.it

Theme 4.3: Crowd behavioral analysis and event recognition
Tutor: Vittorio Murino

Study and development of techniques and systems for the analysis of behaviours, events, social signals in general, referred to a large mass of people (crowd). The analysis and modelling of behaviour of groups and crowd seen as single entities will be considered. There is evidence that large groups of people and crowd are characterised by a collective behaviour which may emerge in different situations and can lead to interesting outcome from the point of view of the surveillance applications, and may help to detect and predict coming events. Machine learning as well as computer vision constitute the focus of this research, starting from early work in human body modelling/tracking to novel social force models able to grasp the complex dynamics of the human flow.
For further details concerning the research project, please contact: vittorio.murino@iit.it

Theme 4.4: Multi-sensory surveillance
Tutor: Marco Crocco

Study and development of techniques and systems for the analysis and processing of signals acquired by multi-sensor devices, with application to surveillance and monitoring. In particular, techniques for multi-sensor data fusion, tracking, and scene analysis and classification will be considered. In this context, different kinds of sensors will considered like optical (single cameras, in the visible spectrum, infrared, thermic), three-dimensional (stereo, LIDAR, etc.) and acoustical devices. As for the latter, special emphasis will be given to audio signals considering single microphones and arrays in different geometric configurations so as to perform acoustic imaging (passive imaging and direction of arrival) for the detection and localization of abnormal audio situations.
The development of algorithms on specialised hardware platforms like DSP (Digital Signal Processor) and FPGA (Field Programmable Gate Array) will constitute an added-value of the research.
For further details concerning the research project, please contact: marco.crocco@iit.it

Theme 4.5: Re-identification using soft biometric cues
Tutor: Marco Cristani

Study and development of biometric techniques for scene analysis and understanding. The research will mainly focus on non cooperative face recognition at distance and person characterization using soft biometrics cues. The idea is to recover the identity of persons as viewed in different times and places, also considering face attributes, the so-called re-identification problem. Not only optical cameras will be used by other information derived from different sensors can be utilized (e.g., range, thermic). Moreover, super resolution techniques could be investigated to increase the resolution of images, particularly for recognition purposes, so as to improve the quality of the images and making them understandable for a human operator or a machine. Another possible option is the use of a pan-tilt-zoon (PTZ) camera able to identify specific features of a single person or groups. The robustness to environmental (real) conditions and the non co-operation of the subjects are the main features to which the developed techniques will have to cope with.
For further details concerning the research project, please contact: marco.cristani@iit.it

Theme 4.6: Structure from Motion in the wild
Tutor: Alessio Del Bue

Multi-view methods for 3D reconstruction have reached considerable results in modelling the structure of the world. However, robust and reliable results are only achievable when the scene observed by a camera is rigid. In a dynamic world, such assumption of rigidity is constantly violated. For instance, in a standard urban scene, objects such as cars and pedestrians move with independent and/or non-rigid motions thus demolishing most of the assumption on which Structure from Motion (SfM) pipelines rely on. This thesis proposal is aimed towards the study of novel and adaptive methods for 3D reconstruction that can model such dynamic scenes using a conjunction of SfM and the input of trained object part detectors. Such system can provide a robust initialisation and the sufficient priors that can increase dramatically the robustness of classical SfM algorithms. The final aim is to obtain a novel framework for multi-view and multi-object Structure from Motion to model a wider range of challenging scenes in Computer Vision. The ideal candidate should have a degree in Computer Science or Engineering (or equivalent) and background in 3D reconstruction from images and/or Machine Learning.
For further details concerning the research project, please contact: alessio.delbue@iit.it

Theme 4.7: Statistical pattern recognition for social computing
Tutor: Marco Cristani

Social computing is a domain focused on the automatic sensing, analysis, and interpretation of human and social behavior from sensor data. Through microphones and cameras in multi-sensory spaces, mobile phones, and the web, sensor data depicting human behavior can increasingly be obtained at large-scale - longitudinally and population-wise. The goal is to integrate models and methods from multimedia signal processing and information systems, machine learning, ubiquitous computing, and applying knowledge from social sciences to address questions related to the discovery, recognition, and prediction of short-term and long-term behavior of individuals, groups, and communities in real life.
For further details concerning the research project, please contact: marco.cristani@iit.it

Theme 4.8: Compressive Sensing in Computer Vision and Pattern Recognition
Tutor: Diego Sona

Compressive sensing (CS) is a recently emerged and rapidly growing research field in signal processing and pattern recognition in general. It investigates ways in which signals can be sampled at rates significantly lower than the Nyquist rate. One of the key concepts in CS is sparsity, that is, the idea that many natural signals are sparse or compressible when represented in an appropriate basis. Thus, original signals can be recovered from pseudo-randomly under-sampled data, using a suitable nonlinear reconstruction algorithm. As a result, sparsity can be exploited to significantly reduce the amount of collected data while improving the sampling rate of significant signal components. Being a relatively novel mathematical framework there is a consistent possibility for relevant advancements. The PAVIS department is in the unique position to access several real-world problems that implies sparsity constraints thanks to the strong collaborations with life science departments in IIT. In particular, research initiatives are active in the fields of neurophysiology, medical imaging, magnetic resonance imaging, and nanophysics.
For further details concerning the research project, please contact: diego.sona@iit.it

Theme 4.9: Social augmentation for robotic platforms using Computer Vision and Machine Learning
Tutors: Alessio Del Bue, Lorenzo Di Natale

Recent research in robotics is trying hard to push robots out of factories and research laboratories. Effective operation in everyday environments requires not only sophisticated and robust perceptual systems but also the ability to detect humans and interact with them. However, treating humans as simple animated entities is not enough: meaningful human-robot interaction entails the ability to interpret social cues and human intentions. Such capabilities are fundamental prerequisites to program the robot to react appropriately to humans and to bias the interpretation of the scene using nonverbal cues (gaze or body gestures).
The aim of this project is to endow the iCub with a fundamental layer of capabilities for detecting humans, their posture and social intentions. Examples could be the ability to detect if a person is attempting to interact with the robot or his posture and intentions. Conventional research in Computer Vision and Machine Learning focuses on applications in which the image patch of a whole person (or group of people) is visible without strong occlusions in. On the other hand, face-to-face interaction requires developing novel algorithms for coping with those situations in which large areas of the body are occluded or only partially visible. This Egocentric (First-Person) Computer Vision is of certain importance and of foreseen widespread diffusion also for humans given the introduction of new compact and wearable devices (e.g. Google project glass prototypes)
This thesis will be carried out within the iCub Facility in collaboration with the Department of Pattern Analysis and Computer Vision (PAVIS). The ideal candidate should have a degree in Computer Science or Engineering (or equivalent) and background in Computer Vision and/or Machine Learning. He should also be highly motivated to work on a robotic platform and have computer programming skills.
For further details concerning the research project, please contact: alessio.delbue@iit.it or Lorenzo.dinatale@iit.it

Theme 4.10: Biomedical image analysis
Tutor: Diego Sona

The activity here mainly aims at studying and developing computer vision and pattern recognition techniques for the analysis of biomedical data, with particular interest in structural data (e.g., still medical images) and functional data (e.g., time-series and videos). The study might focus on various kind of data acquired by biomedical sensors like, for instance, MRI & fMRI, TAC, SPECT, MEG, EEG, etc. The goal is to extract useful information in order to support the expert interpretation in both clinical and research applications.   Possible examples might be computer-aided diagnosis, determination of biomarkers discriminating between healthy and pathological subjects (e.g., schizophrenia, autism, etc.), longitudinal studies for therapies improvement or treatments understanding (e.g., pharmacological), Among the topics to be faced, particular attention will be given to the processing and analysis of multi-dimensional (2D, 3D, 3D+time) and multi-modal images (e.g., MRI+EEG, MRI+PET, etc.).
The PAVIS department is currently involved in research activities with different groups in the neuroscience departments.
For further details concerning the research project, please contact: diego.sona@iit.it

Theme 4.11: Computer Vision for Nanophysics
Tutor: Alessio Del Bue

This project aims at studying and developing novel Computer Vision techniques for the analysis of microscopy data acquired from the most advanced measurement devices hosted in the IIT nanophysics laboratories. The aim is to push forward the boundaries of image analysis techniques enabling real time/fast 3D imaging of thick samples exploiting different configurations achieving super-resolution from cells to large samples (e.g. embryos and cancer cells). In this research, several goals can be identified like image filtering, 3D reconstruction, tracking, visualization (also involving data reduction and redundancy removal), clustering and classification. The expected impact of the project is to open the way to innovative studies at the molecular level on biological samples of interest for Neuroscience and Cancer research.   This project will be supported by highly qualified staff in the Nanophysics/PAVIS facilities and based on a solid collaboration between the two groups. Methodological as well as application-driven solutions will be explored, mainly exploiting probabilistic techniques and compressive sensing methods. The research will be carried out in cooperation with the Nanophysics (NAPH) department of IIT.
For further details concerning the research project, please contact: alessio.delbue@iit.it