ANNEX A-2

University of Genova – Italian Institute of Technology

Doctoral School on "*Life and Humanoid Technologies*"

Academic Year 2011-2012

Doctoral Course on

"*Nanosciences*"

Research Themes

24 positions available with scholarship

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INTRODUCTION TO RESEARCH THEMES

The Italian Institute of Technology (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: 6

Theme 1.1: Surface functionalization of inorganic nanoparticles and nanostructure based on inorganic nanoparticles.
Tutor: Teresa Pellegrino

In order to apply inorganic nanoparticles (magnetic, fluorescent or metallic nanocrystals), or polymeric nanostructures based on combination of different types of inorganic nanoparticles, in biology or in medicine, it is extremely important to engineering the surface of the inorganic nanoparticles/nanostructures. The aim of this research project is to develop i) procedures to transfer inorganic nanoparticles from the organic to the aqueous phase, ii) to functionalize the surface of the inorganic nanoparticles or the nanostructures in order to change properly their surface charge and thus their interaction with charged molecules; iii) to link molecules at their surface for specifically recognition of cells (their functionalization with specific vitamins (i.e. folic acid), or small peptide (like TAT) or antibodies (i.e. $CD44^{+}/CD24^{-}$) or antibiotics are just some examples).

In addition a full study of their optical and/or magnetic properties, together with the structural characterization, their chemical-physical properties, and their colloidal stability will be also part of this project.

Cell toxicity study, cellular specific recognition study and cell sorting tests will be carried out on different cell populations (tumor cells, stem cells, bacteria, etc).

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

Theme 1.2: Synthesis of pH and thermo-responsive polymers and their combination with inorganic nanoparticles for controlled drug delivery.
Tutor: Teresa Pellegrino

In current anticancer chemotherapies a critical drawback is related to the drugs being delivered not only to malignant cells. Existing treatments could be by far more efficient if the drugs could be delivered selectively to the tumour site under defined stimuli. *pH AND TERMOSENSITIVE HYDROGELS* are polymeric nano-beads that are able to undergo volume changes and thus drug incorporation and release under the effect of physical and chemical stimuli like heat or pH. The present PhD project will focus on the development of pH and thermo responsive polymers which can act as nanocontainers for encapsulation, protection, and transport of chemotherapeutic agents. Also, the inclusion of magnetic nanoparticles within the hydrogel will add two additional advantages: it will facilitate the delivery under a magnetic field to a tumour site and at the same time, it will act as a hyperthermia agent to heat locally the nanostructure and trigger the drug release. The candidate should work on the preparation of *pH AND TERMOSENSITIVE HYDROGELS* with a control over the size, shape, composition biodegradability and physical properties. In addition, the combination of the polymeric nanocontainers with magnetic nanoparticles will be a key step in the fabrication of nanostructures able to elicit combined hyperthermia and drug release. The payload, being a drug or a short oligonucleotide sequence, will be encapsulated within the polymeric shell by tuning pH and/or temperature of the medium and, as such, the swelling properties.
For further details concerning the research project, please contact: teresa.pellegrino@iit.it

Theme 1.3: Analysis and modeling of the mechanical behavior of 3D nanoparticles superstructures
Tutor: Alberto Barone, Luca Ceseracciu

Colloidal nanocrystals (NCs) form a family of highly advanced building blocks suitable for large scale assembly of novel high-complexity 1D-to-3D superstructures. Their properties and inter-particle interactions, nowadays, can be highly controlled by tailoring their size, shape, composition and surface functionalization.
In this context particularly innovative appears the possibility of studying and modeling the mechanical behavior of single branched NCs structures, and analyzing how this behavior reflects on the mechanical behavior of more complex 3D assembled superstructures, such as single macrostructures (micrometric interlaced superstructures) and thin/thick films (from randomly to close-packed ordered).
The aim of this research project is to analyze and model the mechanical behavior of novel colloidal branched NCs (e.g. tetrapods, octapods, urchins etc.) and 3D superstructures obtained from their assembly for the production of electro-optical devices (films, macroaggregates, nanocrystal solids). The candidate will have a hand at different techniques for the characterization of the mentioned materials (e.g. AFM, nanoindentation) and will be involved in applying numerical techniques (e.g. Finite Element Analysis) to model the experimental results.
For further details concerning the research project, please contact: alberto.barone@iit.it, luca.ceseracciu@iit.it

Theme 1.4: Synthesis and assembly of nanoparticles into superstructures for applications in photovoltaic devices
Tutor: Liberato Manna

The aim of this research theme is to develop nanocomposite materials for solar cells, by synthesizing new types of nanocrystals and identifying new assembly strategies for such nanocrystals. The assembly and interfacing will be controlled at the nanoscale level and will extend over the large areas required for device fabrication and potential mass-production. We will enhance the photovoltaic conversion by tailoring the electronic properties of the nanostructures, and by exploiting their energy barriers. We will fabricate size-, shape-, and composition-controlled nanoparticles based on a wide range of materials, to be used in blends with oligomers, polymers and tailored ligand molecules. Emphasis will be put on toxicity and impact on environment through the investigation of InP, Cu-, Cu-In-based chalcogenides, and copper oxides as inorganic materials.
For further details concerning the research project, please contact: liberato.manna@iit.it

Theme 1.5: Novel catalytic materials based on nanocomposites for water gas shift reaction and selective carbon monoxide oxidation
Tutor: Liberato Manna

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 porous 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 Assembly of these A-MO heterostructures to form composite materials. **(c)** Catalytic tests.

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

Theme 1.6: Synthesis and assembly of nanoparticles for applications in lithium ion batteries
Tutor: Liberato Manna

The aim of this research theme is to develop nanocomposite materials for lithium ion batteries applications. In lithium ion batteris, the 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 semimetals 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 (from spherical shape to rod like to wire like) is expected to play a role in the battery's overall performance. Electrochemical studies will be followed at every level of the nanostructure's process and upon the cell assembly. As a result of multiple synthetic provisions, there is also an opportunity to refine and modify the cell fabrication process. To sum up, high capacity, 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.

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

NANOSTRUCTURES – ENZO DIFABRIZIO NR. AVAILABLE POSITIONS: 6

Theme 2.1: **Functionalization of scanning probe tips with shape-controlled nanocrystals.**
Tutor: Roman Krahne

Colloidal nanocrystals can function as single electron transistors and as single photon sources. The aim of this work is to position nanocrystals on the apex of scanning probe tips and to explore their optical and electrical properties for advanced scanning probe spectroscopy. In particular, we will target electrically contacted nanocrystals at the extremity of the probe tip that can function as sensors. The candidate will work on the fabrication of electrode structures based on electron-beam and focused ion-beam lithography and investigate the obtained probe tips in scanning probe experiments.
Candidates should have a degree in physics or engineering, experience in scanning probe microscopy or clean room fabrication is a plus.
For further details concerning the research project, please contact: roman.krahne@iit.it

Theme 2.2: Optoelectronic properties of small-scale ordered assemblies of colloidal nanocrystals.
Tutor: Roman Krahne

Our group made great advances in recent years towards the controlled assembly of colloidal nanocrystals into ordered ensembles, in particular of shape-controlled nanocrystals like rods and multipods. The aim of this work is to perform a detailed optical and electrical characterization of such ensembles and to explore their usefulness for optoelectronic device applications. The candidate will fabricate the electronic devices using optical and electron-beam lithography and perform all the measurements like conductivity, optical emission and absorption.
Candidates should have a degree in physics, experience in clean room fabrication (preferably also in electron-beam lithography), and profound knowledge in the physics of semiconductors.
For further details concerning the research project, please contact: roman.krahne@iit.it

Theme 2.3: Micron-size laser devices based on highly emitting nanocrystal structures.
Tutor: Roman Krahne

Nanocrystal heterostructures are a very promising for lasing applications, and our group has demonstrated optically pumped lasing from micron-size assemblies of colloidal core-shell nanorods. The aim of this work is a detailed study of the lasing properties with the aim to significantly improve the lasing performance. In particular, low-power cw pumping and electrical pumping of the devices will be targeted. Candidates should have a degree in physics and solid experience in optical spectroscopy of nanostructures.
For further details concerning the research project, please contact: roman.krahne@iit.it

Theme 2.4: Mid-infrared and Terahertz Nanoplasmonics
Tutor: Luca Razzari

In the last few years, Plasmonics has demonstrated to be an effective way to confine light down to the nanoscale and thus overcome the resolution limit imposed by the radiation wavelength in traditional focusing systems. This has brought to a spectacular set of new investigations, especially in the visible spectral range through Raman spectroscopy. Our aim is now to extend these concepts and achievements to longer wavelengths, in regions (mid-infrared and terahertz) where direct absorption spectroscopy is possible and many molecules exhibit specific vibrational/rotational transitions. The successful candidate will investigate new schemes and design novel plasmonic 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: luca.razzari@iit.it

Theme 2.5: High resolution chemical mapping using tip-enhanced Raman spectroscopy
Tutor: Gobind Das

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

Theme 2.6: Superhydrophobic nanostructures for prrotein aggregation studies
Tutor: Enzo Di Fabrizio

Novel devices based on superhydrophobic effect will be designed, fabricated and used to study protein aggregation in aqueous solution in terms of concentration and shear force modulation. The study will be combined with spectroscopy techniques both in visible/near infrared and synchrotron SAXS (Small Angle X-ray Scattering). The study will aim at proposing that system as an experimental model for Alzheimer disease. Preliminary results published by Nanofabrication group already demonstrated the foundation of this novel hypothesis.
For further details concerning the research project, please contact: enzo.difabrizio@iit.it

Theme 2.7: Plasmonic for photovoltaic applications
Tutor: Remo Proietti

"Photovoltaic" is a very well known word for describing the conversion of sunlight into electricity. Even though the concept dates back some decades, science is still far away from getting photovoltaic devices capable of being cost-competitive with fossil-fuel technologies. One of the main actors responsible of the solar cells high cost is their dimension. In fact, at present most of the solar cells are silicon-based with thickness from 200um to 300um. Keeping constant electricity production with thinner solar cells (nano-meter scale) would result in strong reduction of the production costs. A possible approach in this direction is by merging "plasmonics" with "photovoltaic". The use of the plasmonic properties typical of metallic structures can have a strong effect in the reduction of the spatial dimensions of conventional solar cells. For example, metallic nano-particles embedded in the semiconductor of a solar cell can locally increase the field to obtain high photon-electricity conversion. What we propose is a PhD position with a research theme having the goal of identifying the role that plasmonic can play for realizing better performing solar cells."
For further details concerning the research project, please contact: remo.proietti@iit.it

Theme 2.8: Photonic Crystals with negative refraction.
Tutor: Remo Proietti

Metamaterials are structures showing both negative permittivity and permeability. This characteristic results in peculiar properties of the metamaterials, such as negative refraction which can have strong application for imaging devices. Metamaterials however tend to be fabricated by means of metals which present an intrinsic absorptive property especially in the visible range that is deleterious for any image formation. A possible way around this problem is by using dielectric devices. Here we will theoretically study and fabricate dielectric photonic crystals which can provide, under specific circumstances, negative refraction similarly to metamaterials. We will use our theoretical/simulative findings for the development of a photonic device showing super-resolution effect.
For further details concerning the research project, please contact: remo.proietti@iit.it

Theme 2.9: Study of surface plasmon resonances by means of scanning probe related techniques.
Tutors: Andrea Toma, Bruno Torre

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: andrea.toma@iit.it or bruno.torre@iit.it .

Theme 2.10: Two-photon lithography combined with FIB for advanced plasmonic structures fabrication.
Tutor: Carlo Liberale

The two-photon lithography technique features unparalleled ability, among lithographic methods, to create arbitrarily shaped 3D structures with resolution in the hundred of nanometer range. On the other side, Focused Ion Beam (FIB) related fabrication methods, FIB milling and FIB induced deposition, can achieve extremely high resolution for fabrication\definition of structures in the nanometer range. This PhD projects targets the combination of these two techniques to add their strengths. The candidate will design and create advanced plasmonic structures with unconventional geometries, possibly placed on top of optical fibers, not allowed by traditional lithographic methods, to further extend the field of application of plasmonic probes e.g. for integration with optical tweezers or for measurement on living cells.
For further details concerning the research project, please contact: carlo.liberale@iit.it

Theme 2.11: Development of a nonlinear Raman system for enhanced sensitivity in Raman measurements with plasmonic antennas.
Tutor: Carlo Liberale

Nonlinear Raman techniques as Coherent-Anti-Stokes Raman (CARS) scattering, or Stimulated Raman Scattering (SRS), are powerful spectroscopic methods, which features a signal enhancement by many order of magnitude with respect to spontaneous Raman, and for this reason are rapidly gaining interest. The combination of this techniques with plasmonic probes will further increase their sensitivity, which has been demonstrated down to the few molecules range, allowing for faster measurements which are mandatory e.g. with biological live samples. Moreover, it will be of great interest the possibility to perform time-resolved studies which is open by such a system. The PhD candidate will deal with the implementation of a CARS or SRS setup suitable for combination with plasmonic antenna structures. Then, the candidate will perform measurements in applications ranging from very low concentration detection of molecules (e.g. detection of very low abundant tumor markers), to time resolved measurements of molecular conformational changes down to the single molecule range sensitivity and the "*in vivo*"
For further details concerning the research project, please contact: carlo.liberale@iit.it

Theme 2.12: Optical Tweezers for manipulation of plasmonic probes
Tutor: Carlo Liberale

Optical Tweezers have shown in the last few years their great importance in contactless manipulation of microscopic objects for applications e.g. with biological samples. This PhD project targets the implementation of an Holographic Optical Tweezers system combined with other spectroscopic tools (fluorescence, Raman) for manipulation of suitable plasmonic structures used as probes with extremely high sensitivity and a spatial resolution of few nanometers. This system will allow for mechanical, chemical and functional measurements on environments or with scan geometries that will be impossible to perform with current plasmonic probing methods. The candidate will develop the full system and will apply it for measurements on membrane activity of single live cells.
For further details concerning the research project, please contact: carlo.liberale@iit.it

Theme 2.13: Fiber Optical Tweezers combined with microfluidics
Tutor: Carlo Liberale

Following our recent advances in the realization of Optical Fiber Tweezers, based on an innovative approach presented by our group in the last few years, the PhD candidate will work on the integration towards micro-fluidics systems. The combination of single-fiber Optical Tweezers and microfluidics will allow for a complete integration of optical functionalities as optical trapping and spectroscopic analysis (fluorescence and\or Raman) in a flowcytometer-like device for a lab-on-a-chip biological and medical diagnostic system.
For further details concerning the research project, please contact: carlo.liberale@iit.it

Theme 2.14: The effect of nano-geometry on the growth, proliferation and network formation of neuronal cells
Tutors: Gobind Das, Rosanna La Rocca

The nervous system is a good example of a complex structure that contains many different types of neurons with tree-like morphologies, whose function is largely dependent on their structure. Consequently, to understand how a neuron integrates its myriad synaptic inputs to generate an appropriate response, a thorough understanding of the cell's morphology and geometry is required.
Recent work has provided a basic understanding of signal propagation in networks of spiking neurons. In general, cognitive processing requires signal paths to change dynamically according to the information content of the signal and the processing demands of the receiver. This requires precise control and gating of signal carrying pathways.
Here, we propose a research theme that would analyze the effects of the morphology and geometry of different nanofabricated substrates on the growth, proliferation, network formation and signal propagation of neuronal cells.
The substrates will be realized through advanced micro and nanofabrication techniques, while the behavior of the cells will be analyzed using a variety of different techniques, comprising confocal and atomic force microscopy, and surface enhanced Raman spectroscopy. The influence of parameters like the fractal dimension of the substrates will be investigated.
For further details concerning the research project, please contact: gobind.das@iit,.it or **rosanna.larocca@iit.it**

Theme 2.15: Plasmon Adiabatic Nanoscopy
Tutor: Francesco De Angelis

In the last decade the fields of Raman/Infrared/Terahertz Spectroscopies, 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.
Candidates should have a master in Physics, Chemistry or similar.
For further details concerning the research project, please contact: francesco.deangelis@iit.it

NANOPHYSICS – ALBERTO DIASPRO NR.AVAILABLE POSITIONS: 6

Theme 3.1: Theme: Label free methods in non linear optical microscopy towards tissue engineering.
Tutors: Paolo Bianchini, Alberto Diaspro

New approaches to capture signals from unlabeled biological molecules may finally fullfill 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 differentt and labelling 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 photophysical 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) microscopy. Two-photon excitation (TPE) microscopy can detect some prevalent autofluorescent molecules and SHG methods allow to distinguish fibrillar sturctures. We aim to understand the mechanisms of image formation when using TPE and backward/forward SHG and to use them for the comprhension 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.
For further details concerning the research project, please contact: paolo.bianchini@iit.it alberto.diaspro@iit.it

Theme 3.2: Laser generated nanoparticle in liquid
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 is 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). Candidates should have a degree in physics, physical-chemistry or engineering.
For further details concerning the research project, please contact: romuald.intartaglia@iit.it

Theme 3.3: Synthesis and characterization of novel bio-compatible, bio-degradable and photocurable polymeric materials for deep-UV micro-stereolithography
Tutor: Fernando Brandi

The deep-UV laser micromachining systems of the Nano-Biotechnology Facility, comprising powerful Excimer lasers coupled with micromachining workstations, is suitable for the fabrication of 3D scaffold with controlled porosity and geometry using the micro-stereolithography technique. The produced scaffolds find application in advanced tissue engineering for bone and/or cartilage repair as well as in brain-machine interface.
The aim of the project is to develop, synthesize and characterize novel bio-compatible, bio-degradable and photocurable polymeric materials for deep-UV micro-stereolithography. Activity will include also characterization of the produced scaffolds (morphology, mechanical properties) as well as cell culture and cell viability test performed in collaboration with other IIT Departments. Nano-composite materials will also be produced aiming at the control of specific scaffold properties (surface morphology, wettability, elastic modulus and electric conductivity).
The applicant should hold a degree in polymer chemistry or chemical engineering with experience in synthesis and characterization of polymers.
For further details concerning the research project, please contact: fernando.brandi@iit.it

Theme 3.4: Laser micromachining: fabrication of novel bio-chip
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-biotecnology.
This project will focus on the use of laser based technique for the efficient micro-machining of polymers and hard materials (like silicon and diamonds) aiming at the production of novel bio-chip. Among others, laser drilling will be used for the production on micro-channels to create electric interconnections in diamond based bio-chip, and polymeric membranes for 3D cell culture.
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 physics or engineering with experience in optics, high power laser-matter interaction, and/or material science.
For further details concerning the research project, please contact: fernando.brandi@iit.it

Theme 3.5: Nanoparticles interaction with biosystems: investigating the cytotoxic effect of nanoparticles
Tutors: Silvia Dante, Claudio Canale

The uniqueness of nanoparticles and nanomaterials requires a new experimental methodology for nanotoxicity studies to complement the conventional techniques of traditional toxicology. Understanding the nanoparticle-induced defects in biological membranes is among the major challenges of nanotoxicology. Research on nanoparticle/nanomaterial–membrane interactions needs to go toward understanding the mechanism of interaction which could lead to less hazardous nanotechnologies. Manufactured nanoparticles are potentially capable of inducing defects in cell membranes such as physical disruptions, formation of holes, thinned regions, and may affect essential cellular processing, such as ion transport or signal transduction. Moreover, internalization of nanoparticles may interact with different cell compartments such as organelles, cytoskeleton or cell nuclei. The localization of nanoparticles in living cells will be studied by advanced microscopy techniques. Scanning probe microscopy will applied to investigate changes in plasma membranes and in cell physical properties such as cell stiffness, and the cell adhesion capabilities.
For further details concerning the research project please contact: silvia.dante@iit.it or claudio.canale@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: Super-resolution and advanced fluorescence imaging techniques of large biological samples
Tutors: Francesca Cella, Alberto Diaspro

Super-resolution imaging techniques based on single molecule localization, such as PALM, STORM, GSDIM recently became a powerful tool to investigate protein dynamics and organization at the molecular level [1]. On the other side, light sheet based fluorescence imaging tecniques, such as single plane illumination microscopy [2], provides the optimal tool to perform deep imaging of tissues and large biological samples. The coupling of selective plane illumination microscopy with localization based methods provides a broadening of the affordable applications of super-resolution techniques. Furthermore, techniques based on single molecule detection combined with single-particle tracking and clustering analysis, allow to study the organization and co-localization of biomolecular complexes [3]. The project will involve the improvement of a superresolution selective plane illumination architecture towards the implementation of advanced imaging and analysis techniques. The project will be mainly focused on the implementation of advanced fluorescence techniques, such as single molecule tracking, clustering analysis and fluorescence lifetime measurements, on light sheet based imaging techniques and their applications to large biological samples. Candidates should have a degree in physics, engineering or equivalent.
For further details concerning the research project, please contact: francesca.cella@iit.it
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Theme 3.8: UV laser assisted pyrolysis of organic polymer via radicals formation on semiconductor nanoparticles surface to produce new carbon reach nanomaterials.
Tutors: Riccardo Carzino, Alberto Diaspro

Pyrolysis is a thermochemical decomposition of organic materials that leaves a solid residue richer in carbon content. Inducing the decomposition under irradiation of a solution containing polymers and semiconductor nanoparticles with a short pulsed laser the thermal effect is confined in a small area and in a short time so that the carbon can be restructured in small nanopartcles with different shape and dimension. The interaction of these carbon structures with the semiconductor nanoparticles can give rise to new hybrid species with conductive, optical and thermo mechanical properties useful in different application so that this synthesis could become also a new solution in plastic recycling. The candidate work will investigate the dependence of the process potency on the carbon nanoparticles formation and the properties of the sintered hybrid species. In this activity the student will have the opportunity to profit of the broad spectrum of characterization techniques that the IIT multidisciplinary environment offers.
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or **alberto.diaspro@iit.it**

Theme 3.9 IR-VIS Label Free Nanoscopy
Tutors: Alberto Diaspro, Paolo Bianchini

Chemical and structural imaging with nanoresolution under ambient conditions can significantly '*advance our understanding of biological processes'* at the sub-cellular level, such as understanding the early stages of Alzheimer's disease and lung cancers. Such knowledge of cellular mechanisms is essential for early detection of diseases, to improve the efficacy of therapeutic drugs and to evaluate the real impact of nanomaterials to health and safety. In production processes, the ability to image defects with nanometre resolution is critical for robust quality control of *'industrially important'* products e.g. organic photovoltaic devices, antimicrobial textiles and functional coatings on biomedical implants. We propose a novel imaging label free tool, Infra-Red Nanoscope (IRN) that will significantly improve the lateral resolution from current state-of-the-art 2 μm resolution. This super-resolution in IR microscopy is achieved by non-linear mixing of picosecond IR-pulses and relies solely on the intrinsic IR properties of the material. The goal is to implement a ready to commercialise table-top, nanoresolution, IR-Nanoscope that offers easy operation, flexibility and label free-imaging of the structure and chemistry in both two dimensions (2D) and three dimensions (3D) similar to conventional IR microscopes, common in materials science and biology laboratories. Propedeutic activities on Confocal, multiphoton and super-resolution methods in fluorescence will be carried out.
For further details concerning the research project, please contact: alberto.diaspro@iit.it

Theme 3.10: Observing single-molecule dynamic with STED nanoscopy
Tutors: Giuseppe Vicidomini, Alberto Diaspro

Since 19th century, the spatial resolution of any lens-based (far-field) microscope has been limited by diffraction. The emergence of stimulated emission depletion (STED) microscopy in the last decade showed that, at least for fluorescence microscopy, these limit can be overcome. In a nutshell, a STED beam is injected into a microscope such that it typically produces a doughnut-shape focal pattern featuring a minimum-intensity point overlapping with the maximum-intensity of an excitation beam. The role of the STED beam is to transiently turn off the fluorescent capability of markers except at a subdiffraction-sized region of minimum-intensity. The remaining region in which markers can be fluorescent, called effective point spread function (E-PSF) defines the spatial resolution of the system. The diffraction-limited excitation and STED beams are scanned through the sample and the markers in the subdiffraction-sized region are registered to form the nanoscale image. The possibility to instantaneously provide fluorescent signal from predetermined nanosized regions make STED microscopy not only suited for imaging but also for investigating nanoscale molecular interaction by fluorescence correlation spectroscopy (FCS).
The aim of this research project will be the finalization of a STED set-up based on supercontinuum laser source, the optimization of its performances and the development of dedicated data analysis methods for FCS. The instrument will primarily be dedicated to the study of membrane dynamics in living cells. The candidates should have a background in computer science. Enthusiasm, an interdisciplinary attitude, and a strong team spirit in an interdisciplinary environment are a must.
For further details concerning the research project, please contact: giuseppe.vicidomini@iit.it, or **alberto.diaspro@iit.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 to social force models and dynamic Bayesian networks.
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: Scene analysis by biometric signals
Tutor: Marco Crocco

Study and development of Biometrics techniques for scene analysis and understanding. The research will mainly focus on non cooperative face recognition at distance and person characterization (soft biometrics). The idea is to recover the identity of persons as viewed in different times and places, also considering face attributes. 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 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.
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 4.6: Computer vision in distributed and dynamic camera networks
Tutor: Alessio Del Bue

Study and development of computer vision techniques in the context of small-medium outdoor and indoor camera networks. The scenario will cover several aspects of this problem ranging from the cooperative 3D reconstruction and modelling of unknown environments to higher-level tasks such as distributed pedestrian trajectory analysis and re-identification for video-surveillance. The studied methods may encompass the case where camera networks have dynamic topologies and coverage given by the visual fields of view of the sensors. The development of such algorithms will be supported by the state of the art sensors network deployed in the Italian Institute of Technology and with the support of expert technical staff in video analysis.
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: Minh Ha Quang

Compressive sensing (CS) is a recently emerged and rapidly growing research field in signal processing. It investigates ways in which we can sample signals 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 they can be recovered from randomly under-sampled data, using a suitable nonlinear reconstruction algorithm.
Some of the application domains that are being explored using compressive sensing include medical imaging, seismic imaging, and remote sensing. One example is the exploitation of the sparsity of MR images to significantly reduce scan time and improve image resolution.
For further details concerning the research project, please contact: minh.haquang@iit.it

Theme 4.9: Statistical Pattern Recognition for Bioinformatics and Computational Biology
Tutor: Paolo Piro

Study and development of Statistical Pattern Recognition techniques for the analysis of biological data. Different methodologies will be analyzed, mainly (but not only) in the context of the probabilistic graphical models (Bayesian methods), for both classification, clustering and visualization purposes. The most important application field will be the analysis of proteins for drug discovery applications, in particular structural alignment and more in general proteins' similarity assessment, which are at the basis of structure prediction, function prediction and evolution of proteins. The study will be carried out in cooperation with medical and biological partners, and with the D3 department of IIT.
For further details concerning the research project, please contact: paolo.piro@iit.it

Theme 4.10: Biomedical image analysis
Tutor: Vittorio Murino

Study and development of techniques for the analysis of biomedical data in general, images in particular. The study might focus on whatever kind of data acquired by biomedical sensors like, for instance, MRI, fMRI, TAC, SPECT, etc.. The goal is to extract useful information in order to support the expert interpretation, e.g., Computer Aided Diagnosis, or to help experts in interpreting data coming from pathological and normal subjects (e.g., classification of neuroimaging data for the classification of schizophrenia). Among the topics to be faced, particular attention will be given to the processing and analysis of multi-dimensional and multi-modal images (2D, 3D, 3D+time, MRI+TAC, etc.). Computer vision and pattern recognition, in particular classification and clustering, are among the methodologies that will be considered in this study.
For further details concerning the research project, please contact: vittorio.murino@iit.it

Theme 4.11: GPU Image Processing and Pattern Recognition for Nanophysics
Tutor: Alessio Del Bue

This project aims at studying and developing Image Processing and Pattern Recognition techniques for the analysis of spectroscopy data derived from nanophysics research using graphical processing units (CUDA-like). The main focus will be in the processing of data coming from typical sensors working at nanophysical level like the atomic force microscope (AFM) data, and other kinds of microscopes. In this research, several goals can be identified like image filtering, restoration, reconstruction and super resolution, visualization (also involving data reduction and redundancy removal), clustering and classification. The added value concerns the use of graphical processing units (GPUs) which provides a considerable increase of the processing speed while maintaining the same programming flexibility of standard personal computers. Methodological as well as application-driven solutions will be explored, mainly exploiting probabilistic techniques. The research will be carried out in cooperation with the Nanophysics department of IIT.
For further details concerning the research project, please contact: alessio.delbue@iit.it

Theme 4.12: Visual analysis of human behaviors as evoked by ambient affordances
Tutor: Vittorio Murino

The theme deals with the study of how humans interact with the environment, and specifically it is aimed at focusing on the effect *exerted by ambient affordances on full body motor behavior.* The term object affordance is commonly used to refer to the set of possible actions that a specific object afford to a given agent. For example, a glass can be used to drink, or it can be grasped for washing it. The same applies to the environment. Stairs of a public building can be walked for reaching its entrance, or employed as chairs. During the PhD course, studies will be devoted to understand the affordances of particular architectural or natural elements of the environment. In particular, emphasis will be given in detecting and recognizing How the different classes of actions that can be performed with a given element are modulated by the surrounding space and objects. This course will be highly interdisciplinary: notions of Computer Vision and Pattern Recognition will be studied and explored, as so as notions of Robotics of grasping and de-ambulation will be necessary. Applications of this study can be found in domotics, surveillance, and social robotics to name a few.
For further details concerning the research project, please contact: vittorio.murino@iit.it