PhD in Materials, Mechatronics and Systems Engineering
Dipartimento di Eccellenza /Department of Excellence
Research topics – Cycle 35
Bando 1 / *Call 1, 2019*

Research topics

	Topics	Support
A	Modeling and simulation of vehicle emissions for the reduction of road traffic pollution	Assegno/Fellowship
B	Concurrent design of hardware and control for high-performance robotic systems	Assegno/Fellowship
C	Smart multifunctional hierarchical cellular materials for implants with improved resistance and osteointegration	Assegno/Fellowship
D	Ultrafine particulate matter and nanostructures materials: a comprehensive transmission electron microscopy approach	Assegno/Fellowship
E	Production of multi-material structures by Direct Laser Metal Deposition	Assegno/Fellowship
F	Production of WC-based nanocrystalline materials by electrical field-current assisted technologies	Assegno/Fellowship
G	Field-assisted synthesis/sintering and cold sintering of calcium phosphate-based nano-powders for biomedical applications	Assegno/Fellowship
H	High-Performance Photodetectors based on Engineered 2D Transition Metal Dichalcogenides Layers	Assegno/Fellowship

Topic A

Title	**Modeling and simulation of vehicle emissions for the reduction of road traffic pollution**
Main and secondary SSD	ING-IND/13, ING-IND /22
Supervisor	Daniele Bortoluzzi
Co-supervisor/s (Italian and foreigner)	Francesco Biral (UNITN), Jens Wahlström (KTH, Sweden)
Main objectives	- Develop a mathematical model of the vehicle dynamics - Embed the driving action in the model according to different driving styles - Embed brake, tire and exhaust emission behaviour in the model - Define a total emission index for the vehicle, study the relevant dynamics and correlations with driving style for the different emissions - Explore possible emission minimization strategies

Transversality of the project	The project is based on the integration of the following research areas: Vehicle dynamics (Biral, Bertolazzi, Da Lio, Bortoluzzi) Laboratory of tribology for brake emission data (Straffelini) Emission Analytics Ltd. for exhaust emission data KTH Dept. Of machine design, (Ulf Olofsson) for tire emission data
Project title of the Department of Excellence	This research will contribute to the activities of the project “Study of polluting emissions from vehicle brake systems: current and future projects” and the activities of the Mind_Lab.
Foreign partner with whom the doctoral student will conduct a year of research	KTH – Stockholm – Sweden - General analysis of emissions from key vehicle subsystems - Development of mathematical models of tire emission dynamics - Experimental model validation
Requirements requested	• Master’s degree in Mechatronics Engineering, Mechanics Engineering, Automation Engineering • No specific experience required • Fluent English language both written and spoken
Qualification	Experience in the modeling and simulation of mechatronic systems

Topic B

Title	**Concurrent design of hardware and control for high-performance robotic systems**
Main and secondary SSD	ING-INF/04, ING-IND/13
Supervisor	Francesco Biral
Co-supervisor/s (Italian and foreigner)	Andrea Del Prete (UNITN) Patrick Wensing (University of Notre Dame, US)
Main objectives	Complex articulated robots have the immense potential of serving humanity, freeing us from unhealthy and dangerous tasks, while boosting efficiency in manufacturing, agriculture and renewable energies. However, nowadays, building such machines is highly inefficient. Conventional robot design relies heavily on expert knowledge while decoupling hardware design from control design. As a result, the design/build/test process often requires multiple time consuming iterations of costly robot hardware, leading to systems that fail to reach their full integrated potential. The goal of this project is to overcome this limiting approach, addressing the simultaneous design of hardware and control as a single optimization problem (i.e., co-design). Taking design choices based on how they affect performance will make design simpler, faster, and cheaper, while also improving performance. Main activities: - Investigation of the design of complex robotic systems starting from functional requirements, i.e. a high-level description of the tasks that the system should carry out.

	- Development of a software framework to automate as much as possible the simultaneous design of hardware (i.e. selection of hardware components and their relative placement) and control (including estimation and planning). - Validation of the above-mentioned framework through the manufacturing of robotic system, such as a 3d-printed quadruped robot, or an exoskeleton
Transversality of the project	The subject of this PhD project is extremely multi-disciplinary, involving: ● Mechatronics design/modeling ● System identification ● Optimal control ● State estimation ● Nonlinear discrete optimization Apart from the above-mentioned tutors, several other colleagues are expected to get involved in the project: Marco Fontana for the mechanical design and modeling, Enrico Bertolazzi for the optimal control aspects, Luca Zaccarian for the control of hybrid systems, Paolo Bosetti for the system design and manufacturing.
Project title of the Department of Excellence	MAT4ROB - New materials and structures for actuation and control of robots. This PhD project is strictly connected to the subject of MAT4ROB because it promotes a holistic approach to hardware design, which could even include the choice of materials depending on their mechanical properties.
Foreign partner with whom the doctoral student will conduct a year of research	The University of Notre Dame is a private, non-profit research university in Notre Dame, Indiana, USA. Patrick Wensing is a young assistant professor who recently joined the university after 4 years of post-doc at MIT (with Prof. Sangbae Kim) and a PhD from Ohio State (with Dr. David Orin). The previous experience of Prof. Wensing makes him an ideal partner for this project. Prof. Wensing possesses a thorough knowledge of complex robotic systems as a whole, ranging from high-level planning, software engineering, optimization-based control and identification, all the way down to mechanical design. His experience is supported by a remarkable track record with publications in the best robotics journals and conferences. Prof. Wensing will co-supervise the student throughout the whole project (3 years) through weekly video-conference meetings. During the 1-year stay in Notre Dame, the student will have a chance to work closely with Prof. Wensing, gaining insights of both theoretical and technological tools, such as optimal control techniques for systems with intermittent contacts, and mechanical design of complex electric robotic systems featuring low gear ratios for transparent actuation. The student will be granted free access to the robotic laboratory and all of its equipment. The option of a double PhD degree is currently under evaluation.

Requirements requested	- Master's degree in mechanical/mechatronics/automation/aerospace/software engineering or equivalent - Good computer programming skills - Good English level (at least B2)
Qualification	- Experience working with robotic systems - Experience with optimization and/or optimal control techniques/softwares - Experience with manufacturing/assembly

Topic C

Title	**Smart multifunctional hierarchical cellular materials for implants with improved resistance and osteointegration**
Main and secondary SSD	ING-IND14, ING-IND34, ING-INF01, ING-IND21
Supervisor	Matteo Benedetti
Co-supervisors (Italian and foreigner)	Devid Maniglio (UNITN), Davide Brunelli (UNITN), D. Pasini (McGill University, Canada)
Main objective	This doctoral project is part of a research line that currently attracts considerable interest in the scientific community, namely the development of cellular structure materials to be used in prosthetic implants. The main purpose of these materials is to adapt the rigidity of the implant to that of the surrounding bone tissue and to favor its growth (osseointegration). These requirements are not completely satisfied by the metal implants currently available because they display a massive structure made up of metal materials with elastic modulus far superior to that of the bone tissue. There is already in the literature a great deal of work aimed at the design and construction of metallic materials with a cellular structure, however few of them deal with the subject of fatigue resistance. However, this is a crucial aspect given the fluctuating nature of the loads to which they are subjected in service and to the vast number of failures of similar structures once implanted in the patient. There are various causes that make these structures particularly vulnerable to fatigue damage: (i) the architecture of cellular materials is an intrinsic factor of structural weakening since a full geometry is replaced by a porous architecture consisting of trabeculae joined at particular points termed nodes, (ii) only recently additive manufacturing technologies have been developed able to realize structures with such complicated topology, however they suffer the relatively high degree of immaturity, which is found in the defectiveness of the manufactured articles produced by them, typically in the form of internal porosity, and in the insufficient dimensional accuracy guaranteed by them, especially in cellular structures of sub-millimetric scale, (iii) cellular structures have a very high ratio between external surface and volume, an aspect that makes them very exposed to surface degradation phenomena produced from the environment human in which they are in operation, with further reduction of their fatigue resistance. The innovative idea behind this research project involves designing and manufacturing cellular materials with the following distinctive features:

	1) “hierarchical”: their structure is hierarchical in the sense that it consists of two cellular structures of different dimensional scales: the first macroscopic structure, made of biocompatible metal material capable of guaranteeing dimensional stability over time, carries out a structural "load-bearing" function and is designed to adapt the elastic properties to those of the bone tissue and to maximize fatigue resistance [1]. Since it does not perform osseointegrative functions, its architecture is released from biological requirements in order to be able to scale its dimensions to levels at which current production technologies are able to guarantee an adequate geometric accuracy in order to avoid the problems mentioned in point (ii). Preliminary prototypes have already been produced at the University of Trento with encouraging results. The collaboration with prof. Pasini (McGill University) will also be able to benefit from his internationally recognized skills. The second structure however, not having to comply with structural requirements, has the function of providing an adequate interface to the biological environment, guiding the growth of bone tissue within the prosthesis to favor osseointegration. For this function, both the composition and the morphology play an essential role. Recently, a technique has been developed at the department for the realization of three-dimensional structures (scaffolds) with porosities that can be modulated by means of a foaming process using gas starting from polymer suspensions in water [2]. The technique allows the realization of polymer foams of interest for the regeneration of bone tissue (collagen derivatives or silk fibroin) and allows an easy incorporation of inorganic additives (for example nanoparticulate hydroxyapatite), as well as the realization of pores of dimensions considered optimal for bone regeneration. These foams are currently being studied at the BIOtech center, in collaboration with the group of prof. Van Griensven at the Technische Universität München. From the union of the two manufacturing techniques it is considered possible to create a composite hierarchical structure through the incorporation of the polymeric foam inside the metal bearing structure (preliminary tests are currently underway). 2) “multifunctional”: the hierarchical structure makes these structures multifunctional, since they perform both a supporting and an osseointegration function, furthermore the second-level osteointegrative structure could protect the first from the aggression of the external environment in order to limit the phenomena referred to in point (ii). The fourth function, not least in importance, is to be smart, as explained below. 3) “smart”: a highly innovative aspect of this project is the study of the possibility of incorporating into the second-level polymeric structure of distributed pressure and / or strain sensors with adequate acquisition and processing capabilities for real-time data as is the case for other biomedical signals [3]. The possibility of making these structures smart is extremely fascinating because it would open up the possibility for numerous applications: (i) during the post-operative convalescence phase, the pressure / strain signal coming from the implanted prosthesis and used as an indication of the osseointegration level is monitored of the prosthesis. This allows to establish the moment of complete rehabilitation of the patient and to calibrate the level of physical exercise to the patient's level of healing; (ii) in the normal life phase of the patient

	the prosthesis could be diagnosed periodically in order to detect incipient causes for its failure, for example due to progressive bone resorption; (iii) smart prostheses could also be useful in the in-vitro testing phase thereof, so as to calibrate the mechanical properties of the supporting structure on the basis of the information received from the sensors incorporated therein. References [1] Benedetti, M. et al. "Fatigue and biological properties of Ti-6Al-4V ELI cellular structures with variously arranged cubic cells made by selective laser melting". Journal of the Mechanical Behavior of Biomedical Materials 78 (2018) 381–394 [2] Maniglio, D., et al. "Silk fibroin porous scaffolds by N2O foaming." Journal of Biomaterials science, Polymer edition 29.5 (2018): 491-506. [3] Brunelli, D. et al. "Design considerations for wireless acquisition of multichannel sEMG signals in prosthetic hand control", (2016) IEEE Sensors Journal, 16 (23)
Transversality of the project	The doctoral project is fully in line with the activities foreseen by the activities of the project of the Department of Excellence (flexible and / or wearable mechatronic systems based on multifunctional materials), providing in fact the development of multifunctional cellular materials, whose distributed sensorization can find application also in the other doctoral projects involved. The present doctoral project also has a very marked connection with the following three interdisciplinary department projects: 1) REGENERA: the cellular structures developed in the framework of this doctoral project can also be applied in vertebral prostheses studied by REGENERA. These trabecular structures are in fact capable of satisfying biomechanical requirements (respect for the full functionality of the joint), mechanical requirements (adequate mechanical strength and stiffness comparable to that of the bone tissue that is to be replaced), biological (shape porosity, size and spatial distribution suitable for anchoring the prosthesis to the surrounding tissues and to the circulation of the biological fluids necessary for supporting the cells implanted in the disc prosthesis associated with this medical device). Devid Maniglio's involvement in the project will encourage the exchange of information and skills among all researchers involved in the REGENERA project. 2) 3D printing of inorganic, metallic and composite materials. The technologies used to create the load-bearing trabecular structure are based on additive manufacturing techniques and are therefore fully consistent with the objectives of this interdisciplinary project. The skills acquired in the incorporation of second-level polymer foam into the macroscopic one will also contribute to the development of composite materials obtained by 3D printing. 3) Flexible Sensors for Soft Robotics. Embedding distributed sensors in the second-level polymeric structure will surely benefit from the skills acquired in the framework of doctoral projects related to this interdisciplinary project. The present PhD program of excellence will not only involve the proposing researchers, but dealing with the design of both metallic and polymeric biomaterials, will also involve colleagues in metallurgy (Molinari, Pellizzari), science and technology of polymeric materials (Pegoretti, Fambri), bioengineering (Motta) and industrial design (Cristofolini).

Project title of the Department of Excellence	REGENERA as a priority (see above), but also "3D printing of inorganic, metallic and composite materials" and “Flexible Sensors for Soft Robotics”
Foreign partner with whom the doctoral student will conduct a year of research	The research activity will be carried out in collaboration with prof. D. Pasini, McGill University, Canada, head of the "Architects Materials and Advanced Structures" laboratory. Specifically, the research activity carried out at the foreign partner will focus on topological and structural optimization of cellular structures using advanced finite element analysis tools and homogenization techniques. The doctorate will be carried out jointly and the partner institution will give free access to its research infrastructures. Possible reduced-rate accommodation at the university campus. It should also be noted that the foreign partner university is of absolute international prestige, being placed in different rankings among the top 30 in the world. Such prestigious universities do not easily grant double degrees or exemption from infrastructure access fees. The agreement stipulated in the letter of intent is therefore the maximum that was negotiated with the foreign partner.
Requirements requested	The theme proposed in this doctoral project is extremely vast and multidisciplinary. Realistically, it is not possible for a candidate to possess sufficient skills and time frame to carry out all the planned activities. Necessarily, the candidate will have to focus on one of the macro-themes of the project (development of cellular materials and development of embedded sensors), relying for the development of the remaining theme on solutions already developed or under development in the framework of other excellent doctorates. To allow participation in the competitive tender to the widest possible audience of candidates, it is considered appropriate to require a profile of excellence but not too specific, such as: • Master's degree in material engineering, mechanical, biomedical or electronic or equivalent • Excellent knowledge of English (C1) Based on the competences of the candidate who won the call, the research activity program he has carried out will be calibrated.
Qualification	· Specific experience in the use of design tools, such as CAD and FEM software · Experience in the design of biomedical devices or knowledge of the fundamentals of biomechanics

Topic D

Title	**Ultrafine particulate matter and nanostructured materials: a comprehensive transmission electron microscopy approach. The case of non-exhaust vehicular emissions**
Main and secondary SSD	ING-IND 21; ING-IND 22; CHIM07
Supervisor	Stefano Gialanella

Co-supervisors (Italian and foreigner)	Cinzia Menapace (UNITN), U. Olofsson (KTH, Sweden), Giovanni Straffelini (UNITN)
Main objective	- To develop investigation protocols for fine and ultrafine particulate matter, starting from non-exhaust vehicular emissions. - An essential aspect to be considered is the sampling and sample preparation procedures. - Development of software for combined imaging-spectroscopy-diffraction analyses and data treatment.
Transversality of the project	The project is meant to launch the activity of the newly acquired EM instrumentation, and will provide an essential background to all activities of the Department that would need state of the art characterization of nanograined materials.
Project title of the Department of Excellence	This research will contribute to the activities of the project “Studio delle emissioni inquinanti da sistemi frenanti in autoveicoli”. Moreover, the Project will generate as an important outcome, experimental and data treatments methodologies that will support several activities of the Project “Dipartimento di Eccellenza” requiring materials characterization.
Foreign partner with whom the doctoral student will conduct a year of research	KTH – Stockholm – Sweden The stay at KTH will be particularly focused on: - developing sample preparation protocols using focused ion beam techniques - collecting debris from pin-on-disc tests conducted on brake materials and tire-road tribological coupling.
Requirements requested	- Master’s degree in metallurgy, materials science, materials engineering, chemistry, physics. - No specific experience required. - Fluent written and spoken English.
Qualification	Expertise in materials characterization techniques, with particular regard for electron microscopy, electron diffraction and X-ray spectroscopy. Welcome expertise in tribology and materials science and engineering.

Topic E

Title	**Production of multi-material structures by Direct Laser Metal Deposition**
Main and secondary SSD	ING. IND 21, ING. IND. 14, ING. IND 16
Supervisor	Massimo Pellizzari
Co-supervisors (Italian and foreigner)	Paolo Bosetti (UNITN), Matteo Benedetti (UNITN), Ho Chaw Sing (NAMIC, Singapore)

Main objectives	The main goal of the project is the production of multi-material components by DLMD (Direct Laser Metal Deposition). The fabrication of multi-material components by additive manufacturing (MM-AM), just in the early stages, aims to displace products in single material, paving the way to an incredible number of new scenarios and applications. To to the well-known advantages of 3D printing (efficiency in the use of materials and resources, flexibility of parts and production, reduced delivery times, performance improvement ...), in fact, there is the possibility of creating components in different materials with complex geometries and improved functionality. The work involves the use of the DLMD-DMG Mori equipment, available at the PROM Facility in Rovereto, equipped with a double powder feeding system for the online variation of the type of material to be deposited. Undoubtedly, the combination of different materials places limitations on the manufacturing process. On the other hand, the same process can have limitations towards real applications in terms of dimensional accuracy, dimensions, need for post-treatments, possibility of processing different materials simultaneously under the same environmental conditions. In this perspective, the objectives of the project can be further declined in the following points: 1. Analysis of the chemical, structural and mechanical compatibility of metal joints produced for DMD 2. Study of the deposition parameters on the properties of multi-material metallic components 3. Fabrication of 3D specimens and components 4. Identification of an application case, realization of the prototype and technical/economic validation of the same To better clarify point 4, Figure 1 shows the example of a cam whose head, exposed to high temperatures, is made of Ni superalloy (IN625), while the stem is made of austenitic stainless steel (AISI 316). Amit Bandyopadhyay et. Al. Materials Science & Engineering R 129 (2018) 1–16 Figure 2 shows the example of an Aluminum diecasting mould insert that requires high heating/cooling speeds (reduction of cycle times, improvement of the surface durability of the mould) wear resistance, thermal fatigue and tempering. The combination of a Cu alloy (eg Cu-Be) coated with hot work tool steel is an effective solution that the DLMD technique is able to extend to components of complex geometry, also allowing the creation of compliant cooling channels. M. Pellizzari et. Al. Towards a novel Tool steel-Cu hybrid material. Proc. of 10th Tooling Conference, Bratislava (2016)
Transversality of the project	Materials area (Massimo Pellizzari and Matteo Benedetti, process development and materials characterization), Mechatronics area (Paolo Bosetti, identification and development of industrial application)
Project title of the Department of Excellence	3D Printing of inorganic or metallic materials

Foreign partner with whom the doctoral student will conduct a year of research	NAMiC National Additive Manufacturing Innovation Cluster – Singapore (6 Months) https://namic.sg/technology/ The National Additive Manufacturing Innovation Cluster (NAMIC), led by NTUitive*, was launched in October 2015 to address the challenges, and accelerate Singapore's industrial adoption of additive manufacturing. It identifies and nurtures promising AM technologies and start-ups, jumpstarts public-private cross-collaborations, acting as a connector between industry, research performers and public agencies. NAMIC also assists companies seeking to lower the barriers towards AM adoption through joint project funding and leveraging on its investor networks. - prof. HO Chaw Sing - supports (use of laboratories, purchase of consumables, ...) - co-supervision *Nanyang Technological University (51a Università al Mondo nella classifica Times Higher Education)– NTUitive Pte Ltd ("NTUitive" in short) is the University's innovation and enterprise company. NTUitive supports the University's mission to develop an innovative ecosystem to encourage innovation, foster entrepreneurship and facilitate the commercialisation of research. DMM Mori – Bielefeld, Germany (6 Months) https://dmgmori.com The research and development center of the company that produced the DLMD equipment supplied with the PROM facility has become available to host the doctoral student for a specific training and assist him in manufacturing an industrial prototype.
Requirements requested	• Degree in Materials and Production Engineering, Materials Engineering or equivalent • Specific experience in the field of powder metallurgy and additive manufacturing processes • Good level of knowledge of English (level B1 or higher)
Qualification	- experience in production and characterization of materials and components produced for additive manufacturing - experience in microstructural analysis through optical, scanning and transmission microscopy, X-ray diffraction, thermal analysis (DTA, DSC, dilatometry ...) - experience in measuring mechanical properties of materials through tensile/compressive and fatigue tests - activity of numerical elements with finite elements - competence in the field of measurement, control and processing of signals from sensors and thermal imaging cameras - competence in solid modelling and development of machining cycles using CAM - experience in the use of machine tools

Topic F

Title	**Production of WC-based nanocrystalline materials by electrical field-current assisted technologies**
Main and secondary SSD	ING-IND 22; ING-IND 21
Supervisor	Vincenzo M. Sglavo
Co-supervisor/s (Italian and foreigner)	Alberto Molinari (UNITN) Rishi Raj, Department of Mechanical Engineering, University of Colorado at Boulder (USA)
Main objective	Tungsten carbide (WC) represents a fundamental material in the production of machining tools for metal alloys and friction components (mechanical seals). It is traditionally obtained by high temperature (>1400°C) densification of micrometric powders containing variable amount of Ni and/or Co to activate liquid phase sintering phenomena. Recent studies have pointed out the possibility to reduce by a large extent the sintering times and temperature for the consolidation of ceramic materials through the application of electrical fields and currents. The aim of the present research activity is to analyze and optimize the consolidation process of WC-based nano-powders by the use of specifically tuned electrical fields and currents to be carried out at relatively low temperature for obtaining nanocrystalline structures with higher mechanical properties. Processing conditions will have to be calibrated according to the final performances requested to the material. Quite innovative transport and consolidation mechanisms under said conditions and in a composite material (WC+Co), useful to understand new sintering phenomena activated by the electrical field will have to be analyzed in detail.
Transversality of the project	"Ceramic materials" field; forming technologies and consolidation; transport processes in nanometric structures "Metallurgy" field: tailoring and control of sintering "Mechanical machining" field: surface properties, friction and wear
Project title of the Department of Excellence	Manipulation of material by electrical or electro-magnetic fields
Foreign partner with whom the doctoral student will conduct a year of research	Prof. Rishi Raj, Department of Mechanical Engineering, University of Colorado at Boulder (USA) Analysis of materials structure and optimization of treatments suitable for their transformation; lab facilities and instrumentation will be available at the hosting University. According to existing agreement between DII and the Department of Mechanical Engineering, University of Colorado at Boulder the possibility of a double degree will be evaluated (although it will for sure require an additional year)

Requirements requested	Laurea magistrale – Master's degree in scientific disciplines and in particular in materials engineering, chemical engineering, materials science or affine disciplines. Research experience or final project / thesis on metal alloys, ceramics or composites. Good English knowledge (spoken and written).
Qualification	Publications coherent with the research topic

Topic G

Title	**Field-assisted synthesis/sintering and cold sintering of calcium phosphate-based nano-powders for biomedical applications**
Main and secondary SSD	ING-IND 22; ING-IND 34, CHIM-07
Supervisor	Vincenzo M. Sglavo
Co-supervisors (Italian and foreigner)	Antonella Motta (UNITN), Sandra Dirè (UNITN) Rodrigo Moreno, Istituto de Ceramica y Vidrio, Madrid, Spagna
Main objectives	Recent reseach activities have demonstrated the possibility to sinthesize and consolidate inorganic nano-powders by processes activate through electrical fiels or microwaves. Other very recent studies have demonstrated that nanometric structures, also composite (metal-ceramic) can be densified at very low temperatures (close to room temperature) by the so called "cold sintering" technique. The aim of the present work regards: - the synthesis of calcium-phosphate – based nanopowders by electric field or microwave – assisted processes; - the consolidation of nanopowders for the realization of porous scaffolds including also organic components (inerts – for improving the fracture resistance or bioactive – for increasing the biocompatibility or osteoconductivity) or the the production of coatings on metal suvbstrat3s by "flash sintering" or "cold sintering"; - the study of possible physical-chemical mechanisms involved in said synthesis and consolidation processes - the realization of bioactive matrices suitable for the regeneration or the substitution of a vertebra.
Transversality of the project	"Materials engineering" field: forming technologies and consolidation "Materials chemistry" field: systhesis of nano-powders by solution methods and chemical / physical / structural characterization "Biomedical technologies and bio-engineering" field: final component design, identification of the bioactive organic component, evaluyation of the biocompativility / bioactivity of the produced materials
Project title of the Department of Excellence	A. REGENERA: Designing and fabricating a vertebra and intervertebral disc regenerative prosthesis, a platform for bone tissue engineering B. Manipulation of material by electrical or electro-magnetic fields

Foreign partner with whom the doctoral student will conduct a year of research	Prof. Rodrigo Moreno, Istituto de Ceramica y Vidrio, Madrid, Spagna Study of nano-powders, realization of colloidal suspensions and forming technologies
Requirements requested	Laurea magistrale – Master's degree in scientific disciplines and in particular in materials engineering, chemical engineering, materials science or affine disciplines Research experience or final project / thesis on ceramic materials or composites Good English knowledge (spoken and written)
Qualification	Publications coherent with the research topic

Topic H

Title	**High-Performance Photodetectors based on Engineered 2D Transition Metal Dichalcogenides Layers**
Main and secondary SSD	ING-INF/01 – CHIM/07 – FIS/01
Supervisor	Lucio Pancheri
Co-supervisors (Italian and foreigner)	Sandra Dirè (UNITN); Alberto Quaranta (UNITN); Emil List-Kratochvil (Humboldt-Universität zu Berlin, Germany)
Main objectives	The aim of this research activity is the development of novel optical detectors based on transition metal dichalcogenide (TMDC) materials, with particular focus on MoS2. Detectors based on this class of ultra-thin materials, consisting of a few atomic layers, can efficiently absorb electromagnetic radiation in a wide spectral range from ultraviolet to near infrared, converting it into an electrical signal. The proposed research is a hot topic and will leverage on the results already obtained during the last year activity in the frame of "Flexible sensors for soft robotics" project and in particular within "MILA" (CARITRO Foundation project), which demonstrated the feasibility of large-area MoS2 films with excellent uniformity grown by alternative fabrication routes as sol-gel and ion jet deposition. In particular, 2H-MoS2 thin layers have been produced for the first time by sol-gel processing even on flexible substrates, and the potential use for electronic applications was demonstrated through the study of their memristive behaviour. The active TMDC materials will be grown using industrially scalable technologies and their optical and electrical properties will be optimized using proper functionalization methodologies. The morphological and electronic properties of the materials will be analyzed using the instrumentation available at the host institution, whose researchers were already involved in the characterization of electronic and physical properties of sol-gel MoS2 layers and co-authored a paper published on a high IF journal.

	The detectors will be processed using both well-established and new deposition techniques and will be characterized with respect to their electro-optical properties. Flexible substrates and electrode materials will be chosen with the goal of obtaining a high degree of conformability in the final devices. The main novelty of the proposed activity lies in the realization of detectors combining wide spectrum, high sensitivity and flexibility, that are enabled by the ultra-thin sensing layer and the versatility in the choice of the materials. The devices realized in this activity will find applications in the sensing of biological parameters (pH, indicators of oxidative stress) and pressure, exploiting their conformability to realize a minimally invasive readout system for optical sensors based on light absorption, scattering and fluorescence. The sensors could also be embedded in prototypes for the validation of regenerative prostheses and used for pressure sensing in soft robotics.
Transversality of the project	The research activity involves different areas at DII (electronics, materials chemistry and materials physics), at the Humboldt- Universität zu Berlin (nanofabrication and electronics). In particular, at DII the chemistry and characterization labs will be used for the synthesis (S. Dirè) and characterization of the materials (A. Quaranta) and the electronics lab for the design and characterization of the devices produced also exploiting the facilities of FBK (L. Pancheri). Strong interdisciplinarity is essential for the success of this activity: material characterization results will be used to the definition of electro-optical models to be implemented in a TCAD device simulator, that will be used both in the design phase and in the analysis of experimental data.
Project title of the Department of Excellence	The proposed activity is performed in the frame of the project “Flexible Sensors for Soft Robotics”, and considering the envisaged applications it is also connected with both REGENERA and MAT4ROB projects.
Foreign partner * with whom the doctoral student will conduct a year of research	Prof. Emil List-Kratochvil will co-supervise the research activity at the Physics Department of the Humboldt-Universität zu Berlin that will include the substrate engineering and production and the characterization of detectors by means of cutting-edge techniques not available in Trento. The student will have access to the department facilities for the devices production (deposition and nanolithography techniques) and the characterization of both materials (SES, AFM, Kelvin probe) and devices (electrical and electro-optical measurements) The host institution will give assistance to the PhD-fellow in exploiting the opportunities for accommodation and meals.
Requirements requested	Master’s degree in materials science, materials engineering, physics, chemistry and related degrees. English proficiency: B2, possibly C1
Qualification	Simulation/experimental activity on electronic devices or sensors