ISTITUTO ITALIANO DI TECNOLOGIA | PhD@IIT

Research Topics for **Doctorate in Bioengineering and Robotics,** curriculum in **Bionanotechnologies**

Research Topics

1. Green Nanomaterials for development of Conducting Inks, Circuits and Sensors for Flexible Electronics

Tutor
Athanassia Athanassiou

Research Lab
Smart Materials Research line, IIT, Genova

Description
The word 'electronics' signifies PCBs, chips, circuits and metallic wires but the current trend points towards light-weight, flexibility, eco-friendliness and non-toxic materials. Flexible electronics have been evolving to transform consumer electronic devices to robust wearable devices, whereas "the internet of things" acquires increasing presence in such electronic devices, though new sensors. This could translate in increased use of plastics in consumer electronics and generation of more persistent plastic and electronic waste. Therefore, development of sustainable flexible electronics is becoming critical.

The aim of this PhD research program is to design and develop innovative, sustainable, flexible plastic electronics that can feature several simultaneous desired properties, such as flexibility, bending and folding resistance, conformable to irregular surfaces, biocompatibility, high sensibility, speed and long lifetime. Use of conductive polymers and new 2D electrically conductive nanomaterials such as graphenes, carbon nanofibers, transition metal carbides and nitrides (MXenes), and their hybrids in combination with biopolymers, or natural polymers will

be used in the fabrication of these systems. This PhD program will be implemented in close collaboration with IIT Robotics groups and the developed sustainable electronic materials will be adapted to certain robotic elements such as flexible capacitors, electrodes, sensors, PCBs, and conductive robotic lining with proper circuit and device design. Specific objectives of this research will be the development of flexible, stretchable and biodegradable conductors as coatings or free standing films. Extensive electrical, mechanical, thermal testing and micro-morphological characterization will be made.

The student will have the opportunity to develop research collaborative projects under the new Sustainability Initiative promoted within IIT. In particular, the work will focus on the UN Sustainable Development Goals 9, 11 and 12.

Requirements
Applicants are expected to have a Master's Degree in one of the following areas: Material Science, Chemical Engineering, Physics with materials science specialization and specific focus on Electronics. The candidates should preferably have experience in electronics in the form of summer internships or preparation of undergraduate research projects. Good experimental and English language speaking and writing skills are required.

References

- P. Cataldi, et al., Keratin-Graphene Nanocomposite: Transformation of Waste Wool in Electronic Devices. ACS Sustainable Chemistry & Engineering, 7, 12544-12551, 2019

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2. Design, Characterization and Application of Functional nano-emulsions for Sustainable Materials

Tutor
Ilker Bayer

Research Line
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Description
Many industrial surfactants in use today including home cleaning products contain compounds that pose severe environmental problems related to our water resources and extra cost to water recycling. In addition to transforming these surfactants to bio-based and biodegradable and non-toxic counterparts, ecofriendly and surfactant-free emulsions that are stabilized by natural

polymers such as polysaccharides in the form of nanoparticles or dispersions are becoming more and more preferred both in industry and academic research. In this project, the PhD student will develop novel ecofriendly emulsions with applications ranging from printing conducting electronic inks to biomedical and food grade functional coatings. The student will extensively use nanoscale materials such as graphene, boron nitride and ceramic nanomaterials as well as functional natural organic compounds such as nano-cellulose and polyphenols to formulate electrically or thermally conductive as well as antioxidant and antibacterial emulsions. The emulsions will be applied in areas such as flexible electronics, thermo-regulating textiles, and food preserving coatings. The student will learn transforming these emulsions into coatings on various challenging surfaces such as textiles, moving interfaces, soft materials and food contact interfaces including other 2D or 3D architectures or scaffolds and extensively characterize their function and physicochemical properties. The student is expected not only to establish collaborations with other researchers in the Smart Materials group but also with other IIT departments such as robotics and nanochemistry.

Requirements
Applicants are expected to have a degree and laboratory experience on chemical engineering, material science chemistry, physics or related disciplines. Interests in experimental work in the lab and good command of English language.

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3. Soft Materials for Water Harvesting

Tutor
Despina Fragouli

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Description
Water scarcity is one of the most important problems of the modern society. Among the different strategies adopted to face up this problem, the recovery of water from various sources is of crucial importance. In particular, unconventional sources such as seawater, atmospheric humidity, industrial discharges and domestic sewage contain water, which can be recovered following advanced water technologies. Current approaches combine diverse traditional water treatment processes, which require complicated procedures and enhanced energy

consumption, with, often, limited performance. For this reason, alternative methods are explored with highly efficient cost effective materials able to perform with minimum energy consumption. The aim of this PhD research program is the development of functional porous polymer composites, able to recover clean water from polluted sources using as a unique source of energy the solar irradiation. The focus will be on materials with specific affinity to water and with photothermal properties, i.e. the ability to heat up locally under solar irradiation. Such photothermal composites will be able to absorb and transform solar energy into heat, in order to drive the evaporation of water from polluted sources, succeeding thus in the collection of the purified water via vapor condensation. Materials deriving from food or agricultural wastes and/or highly efficient composite hydrogels will be explored as the photothermal material always targeting on systems with unique nanostructures, low-cost, abundance, and low environmental-impact.

Requirements

The ideal candidates are students with a Bachelor's Degree in one of the following areas: Bioengineering, Material Science, Chemical Engineering, Physics and Chemistry. The candidates should preferably have further experience in the field of water remediation in the form of summer internships or of undergraduate research projects. Good experimental and English language speaking and writing skills are required.

References

1. S. L. Loo, L. Vásquez, M. Zahid, F. Costantino, A. Athanassiou, D. Fragouli "3D Photothermal Cryogels for Solar-Driven Desalination" ACS Appl. Mater. Interfaces 2021, 13, 26, 30542–30555.
2. M. S. Zafar, M. Zahid, A. Athanassiou, D. Fragouli "Biowaste-Derived Carbonized Bone for Solar Steam Generation and Seawater Desalination" Adv. Sustainable Syst. 2021, 5, 2100031.

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