UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"3D Nano- and Microstructures for Sustainable and Flexible Energy Devices"

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Short Abstract:

Fabrication of 3D nano- and microstructures has become crucial for developing new sustainable energy solutions. These innovative structures can improve the efficiency of devices for energy production, storage, and conversion, such as batteries, solar cells, and supercapacitors. Microsfabrication techniques enable extreme precision and flexibility, which are essential for optimizing energy performance while reducing material consumption. These advances also promote the development of flexible, energy-efficient electronic devices suited to new technological demands and particularly wearable technologies. By integrating sustainability, these research efforts help reduce the environmental impact of energy technologies. The ability to produce complex nano- and micro-scale structures opens new possibilities for increasing storage capacity and efficient renewable energy storage systems. Moreover, these innovations support the transition to a more environmentally-friendly society by promoting the use of responsible and more effective materials. Mastering these advanced techniques could transform the energy sector, making it more sustainable, flexible, and accessible.

This course is dedicated to the principle of electrochemical energy storage for microelectronics. It will be presented recent progress achieved in the field of microbatteries for powering sensors, lab-on-a-chips, e-textiles, medical patches, etc. The principles will be explained in terms of basic electrochemistry and thermodynamics. The relationship between properties at the atomic level with the performance of the power sources will be highlighted. Particularly, an insight into the use of micro-nanostructured materials to improve the storage capacity, rate capability, and cyclability will be given. Advanced manufacturing techniques to realize 3D structures like lithographic techniques and Atomic Layer Deposition (ALD) will be also emphasized.

Course Contents in brief:

I. Basics of electrochemistry

- Redox reactions
- Thermodynamics of redox reaction

- Kinetics of redox reaction (activation and diffusion processes)
- The electrochemical interfaces

II. Electrochemical analysis techniques for the characterization of energy storage systems

- Potentiodynamic and potentiostatic experiments
- Current and potential transients
- Cyclic voltammetry
- Charge and discharge profiles
- Electrochemical impedance spectroscopy

III. From the Lithium-ion technology to the design of microbatteries

- Principle and applications
- The negative electrodes for microbatteries (C, oxydes, Si, …)
- The positive electrodes for microbatteries (spinels, …)
- The different electrolytes for microbatteries
- Towards the next generation of microbatteries

IV. Microfabrication processes for designing microbatteries

- Optical lithography
- Electron- and ion-beam lithography
- Thin-film deposition of battery components (top down and bottom-up)
- Recent examples dedicated to the fabrication of energy storage microsystems
- Flexible microbatteries
- Beyond Li-ion technology (Na-ion, K-ion, etc.)

Total # of hours of lecture: 20

CV of the Teacher

Prof. Thierry Djenizian is the head of the flexible electronics department at the Ecole Nationale Supérieure des Mines de Saint-Etienne (Campus Georges Charpak). In 2002, he received his PhD degree in Materials Chemistry for microelectronics from the Swiss Federal Institute of Technology in Lausanne and the Friedrich Alexander University of Erlangen-Nuremberg. His research activities are mainly focussed on the nanostructuring of materials by electrochemical techniques for applications in energy storage and conversion at the micrometer scale & design of flexible microelectronic devices for wearable technologies He is the author of over 140 publications in international journal. He is one Conference Chair of Porous Semiconductors Science and Technology international conferences.

Final Exam: Written Test

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

June 9–13, 2025: 9:00–13:00 AM