PhD in Physics

Research Title: Advanced sustainable materials and processes for electrochemical energy harvesting and storage devices

Electrochemical energy harvesting and storage

Funded by	Ateneo Internazionalizzazione su fondi della Fondazione Compagnia di San Paolo

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Context of the research activity	This proposal has an extremely multidisciplinary nature which is placed in the field of electrochemical energy storage devices, such as supercapacitors, and more generally in the study of the interfaces between ionic liquids and porous conductive electrodes (phenomenon also at the basis of some energy harvesting systems). Supercapacitors (SCs) are a complementary energy storage solution to secondary batteries. The high-power capabilities and extremely long-life cycle of supercapacitors are shifting the focus to coupling these devices in order to complement the properties that lead to more efficient energy storage solutions. The higher power density of supercapacitors is a direct consequence of the accumulation mechanism which is based on the balancing of the electrostatic charge (in the case of electric double-layer capacitors) and / or superficial and fast redox reactions (in the case of pseudocapacitive devices). Ionic liquids (IL) are salts dissolved at room temperature and consist of an organic cation and an inorganic or organic anion. There is a wide variety of possible structures and this flexibility allows the ILs to be designed according to the specific needs of an application (task specific IL) making them more versatile than conventional electrolytes. A second strong point is linked to their negligible vapor pressure and their high thermal and electrochemical stability thanks to their ionic nature.

	The aforementioned supercapacitors can draw considerable advantages from the use of electrolytes based on ionic liquids both from the point of view of electrochemical performance and as regards their stability. However, in order to fully exploit their potential, it is necessary to fully understand the physico-chemical properties of the materials involved and the charge accumulation mechanisms in these systems in order to try to maximize their performance by appropriately combining the active materials in these devices. Finally, the research activity will be carried on in collaboration with two EU universities, center of excellence in the field of electrochemical devices: the Bremen University (Faculty of Production engineering and Advanced Energy Systems Institute) and the Jena University (Center for Energy and Environmental Chemistry).

Objectives	Through the work of the PhD student and the collaboration between the Bremen University (Faculty of Production engineering and Advanced Energy Systems Institute) and Jena University (Center for Energy and Environmental Chemistry), we intend to deepen the use of ionic liquids in electrochemical energy harvesting and storage systems. In particular, the synergistic effort of the three research institutes will make possible to: - Develop and characterize innovative materials to be used as electrodes (PoliTO) - Develop and characterize innovative ionic liquids for use as electrolytes (Jena) - Characterize and model these combined systems by means of electrochemical impedance spectroscopy (Bremen) Particular attention will be paid to the sustainability of the investigated processes. Research on energy storage devices is in fact recently trying to find green paths for their manufacture. In particular, there is a transition to processes with lower cost and environmental impact. The main research objectives of this PhD thesis include (not necessarily all): ○ Design, fabrication and electrical/electrochemical characterization of a customized supercapacitor or newly designed energy devices. ○ Innovative electrodes - study and development of innovative materials for electrode fabrication able to exploit both electric-double layer formation and its possible expansion to harvest energy exploiting the capacitive mixing ○ Innovative electrolytes - characterization of innovative materials to be used electrolyte.

Skills and competencies for the development of the activity	Master Degree in the field of Physics, Engineering, Material science, Nanotechnology, Electronics Basic knowledge in Solid State Physics, Semiconductor Physics, Material Science