



PhD in SCIENZE E TECNOLOGIE ENERGETICHE E NUCLEARI / ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY - 37th cycle

THEMATIC Research Field: HIGH MN, LOW CO AND LOW NI CATHODES FOR LITHIUM BATTERIES..

Monthly net income of PhDscholarship (max 36 months)

€ 1400.0

In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity

Motivation and objectives of the research in this field

In lithium-ion batteries (LIBs), the cathode material is considered as the bottleneck of battery technology since it often delivers a capacity below half of those of anodes and thus limit the energy density of a battery. An efficient way to promote the cathode capacity is to replace Co in the conventional cathode material (LiCoO_2) by Ni, and prepare $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ ($x \geq 0.3$), so called high Ni layered material. However, as Co is progressively substituted by Ni, the reactivity of the cathode surface increases, which reduce the cycling stability of the cell and generate safety issues. Besides, with the market penetration of electrical vehicle foreseen within the next 10 years, the cost of Co and Ni (the most costly and toxic elements in a LIB) are expected to skyrocket. Thus, it is urgent to propose new compositions that have low content or even free of Co and Ni, which show higher capacity and good structure stability. In this regard, layered structured high Li and Mn cathode materials, $\text{Li}_{1+x}[\text{Mn}, \text{Ni}, \text{Co}]_{1-x}\text{O}_2$ will be prepared and used as cathode material for LIBs. This type of material can exhibit ultra-high capacities ($> 250 \text{ mAh/g}$ vs. 150 mAh/g for LiCoO_2), but suffer from structural degradation during cycling. To address these problems and realize a Li/Mn-rich material with the potentially practical application, different strategies, including surface coating, element doping, design of the bound orbital of the transition metals, tailoring the oxygen defection in the 1 / 3



	material structure etc. will be applied in this project. Besides the direct use as cathode material, the second application of Li/Mn-rich material is proposed to be the prelithiation agent for lithium metal anode in lithium metal batteries. This idea is inspired by the fact that this type of materials often shows poor initial coulombic efficiencies (lower than 80 %) due to the employment of poor reversible oxygen redox. Although this is a drawback as a cathode, when using as prelithiation agents, the advantage shows up, i.e., an excess of lithium can be plated on the Li metal anode during the first charge and ensure that all the remaining cathode capacity (provided by a highly stable cathode insertion material) is used in the following cycles. This excess lithium compensates the lithium loss from anode due to the formation of interfacial layer at the anode surface that enable the stability of lithium metal (vs. the electrolyte).
Methods and techniques that will be developed and used to carry out the research	This project will be first carried out by combining ceramic synthesis, cell fabrication and electrochemical test. After finding good compositions/chemistries that show enhanced capacity as cathode or promising performance as prelithiation agent for Li metal anode, different characterizations, including structure, morphology, surface chemistry etc. will be applied to have complete evaluation of them. Meanwhile, understanding of the electrochemical behaviors of these materials will be conducted with different in situ techniques, and the degradation of crystal structure will be studied by post mortem analysis. Part of this work is planned to be achieved with external partners.
Educational objectives	The student will acquire deep knowledge of lithium-ion batteries, including synthesis, characterization and evaluation of cathode materials. He/she will learn how to find and address issues with efficient strategies.
Job opportunities	Advanced material companies, battery companies, automotive companies etc.
Composition of the research group	1 Full Professors 2 Associated Professors 0 Assistant Professors



	3 PhD Students
Name of the research directors	Prof. Jie Li

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	564.01 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The PhD scholarship is financed by the Energy Department's "Excellent Departments Program". Educational activities: Financial aid per PhD student is available for purchase of study books and material, funding for participation in courses, summer schools, workshops and conferences, instrumentations and computer, etc. The amount is about Euro 3.100,00. Teaching assistantship: Availability of funding in recognition of supporting teaching activities by the PhD student. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations. Awards: Awards will be recognized to the PhD candidate up to Euro 1.500,00 (gross amount, after completion of the 3rd year). More details about this program will be provided by PhD Program. Computer availability: individual use. Desk availability: individual use.