POLITECNICO DI MILANO

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

THEMATIC Research Field: ANODELESS' LITHIUM-METAL BATTERY SURFACE TREATMENTS AND RELATED ELECTROLYTES DEVELOPMENT..

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	Lithium-ion batteries are reaching their theoretical limits in terms of energy density and next generation batteries requires higher capacity electrodes. Besides, with the market penetration of electrical vehicles foreseen within the next 10 years, the costs of Co and Ni, the most costly and toxic elements in a lithium-ion battery, are expected to skyrocket.Thus, it is important to develop battery chemistries and design that allow, at the same time, a lower environmental impact, lower costs and higher energy densities. The negative electrodes in current Li-ion batteries is made of graphite, including in the best cases 10% of silicon for reaching capacities of ca. 500 mAh g-1 . On the other hand, lithium metal, used in primary lithium batteries and lithium metal polymer secondary batteries offers 3860 mAh g-1. However, its use is hindered by the difficulty to plate lithium homogeneously since dendrites tend to form easily upon charge, which poses a serious safety risk and is extremely detrimental to battery performance. Moreover, the handling of the lithium metal requires a well-controlled environment (i.e. dry-rooms) which makes lithium-metal batteries manufacturing costly. On the other hand, lithium-ion batteries are manufactured with graphite and lithiated positives electrodes and assembled in the discharged state (i.e. when both positive and negative electrodes are compatible with ambient conditions, the battery is then sealed after electrolyte 1 / 3

	injection and charged in the factory. Together with the suppression of lithium dendrites with insertion anodes, it is one of the reasons of the success of lithium-ion batteries vs. lithium-metal batteries. Most cathode materials are prepared under their lithiated form, which means that they already contain the lithium needed to operate a battery. It then shuttles from the positive to the negative electrode during charge and discharge. This, in principle, could also be realized with lithium-metal batteries to limit the excess of lithium metal present in the cell and increase the energy density while drastically reducing the manufacturing costs. However, homogeneous plating of lithium metal on Cu is even more challenging than on Li due to the mismatch of the crystalline lattices. Thus, surface treatment are required to favor homogeneous nucleation of and deposition of lithium during charging steps. The project thus deals with treatment of the Cu surface by electrochemical and physical treatment as well as the deposition of various layers and the tuning of plating conditions and electrolyte to improve the first plating and the cycling performance.
Methods and techniques that will be developed and used to carry out the research	The project will start from (i) understanding the issues of lithium plating and developing non-destructive electrochemical methods tools to follow the quality of the lithium deposits. This approach will be validated vs. exsitu and post mortem characterization, carried out with suitable partners, allowing to correlate electrochemical signals and deposit morphology.
Educational objectives	The fist students will acquires deep knowledge of lithiumbased batteries and testing and learn how to address a multicomponent problem that, often prevents accurate predictions due to overlapping effect (i.e. morphology charge, formation of passivation layer, inhomogeneous concentration gradients etc?), by studying various operating conditions to highlight one or the other issues.
Job opportunities	Battery, automotive, advanced materials and components sectors, consulting companies

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Composition of the research group	1 Full Professors 2 Associated Professors 0 Assistant Professors 3 PhD Students
Name of the research directors	Prof. Elie Paillard

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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.