



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

THEMATIC Research Field: BATTERY AGEING FROM A MATERIALS-SCIENCE PERSPECTIVE..

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

Batteries, of different chemistries and technologies, are expected to operate for several thousands of cycles at variable temperature and discharge rates, to meet present and next-generation application standards. Performance decay is caused by a range of entangled physico-chemical processes, involving active and non-active electrode materials, as well as the electrolyte and ancillary components. In part, these processes take place at the electrode/electrolyte interface, as a result of the evolution of the active material under charge/discharge conditions, and its electrochemical interaction with the electrolyte, but quite often involve the modification of the electrolyte or the separator, as well as transfer of materials across the cell ζ causing electrode poisoning - and current-collector corrosion. Finally, mechanical failure of the electrode and loss of electric contact can yield electrochemically inactive areas. Commonly, accelerated ageing protocols are employed to speed-up the degradation processes and predict lifetime, as impacted by operating parameters, such as temperature, discharge/charge rates, cut-off voltage and depth of discharge. The traditional, purely electrical tests are not entirely satisfactory to attain a thorough understanding of battery ageing: next-generation research will thus require extensive input at the electrochemical materials-science level, regarding the evolution of materials under realistic conditions. This



	scenario motivates doctoral research on the degradation of battery materials, based on the direct monitoring of materials properties.
Methods and techniques that will be developed and used to carry out the research	The first stage of the research, will revolve around <i>post mortem</i> analyses of single cells, both of laboratory and commercial scales. The cells will be aged with electrochemical protocols at controlled temperature, representative of real-life operation. After ageing, the cells will be disassembled and portions of the components ? with special attention to electrodes ?, will be analysed and compared to the same components in pristine state. At this stage of the investigation, common materials-science methods will be employed, such as scanning electron microscopy (SEM) and X-ray diffraction (XRD). Materials extracted from aged cells will be used to reassemble laboratory cells, to determine the nature and evolution of their electrochemical properties and correlate them with materials parameters. Specifically, the tests will be conducted using electrode parts taken from different portions of the cells and from different positions in the electrodes, to detect non-homogeneous ageing effects. The second stage of the research will be centred on state-of-the-art surface-science tools, such as and X-ray photoemission spectroscopy (XPS), XPS microscopy and X-ray absorption spectroscopy and microspectroscopy, that will yield a more insightful understanding of chemical state issues and their space distribution. The third stage of the study will be devoted to the development of <i>in situ</i> and <i>in operando</i> spectroelectrochemical monitoring tools. The focus will be on dedicated cells, capable of supporting real operating conditions, in view of achieving results that can be fed back to the design and production of industrial-scale batteries.
Educational objectives	The PhD candidate is expected to: (i) develop an interdisciplinary, multi-technique approach for tackling battery studies from the point of view of materials science and engineering; (ii) set up methodology and protocols for space- and time-resolved analyses of battery materials, as implemented in real devices; (iii) devise novel routes



	towards next-generation in operando monitoring.
Job opportunities	The abilities developed by the PhD candidate, on the one hand are currently scarcely available are rarely combined with an engineer's background and, on the other hand, are starting to be actively required by a large number of industries that need to optimize the operation of batteries and extend their useful life. The candidate's profile will be highly attractive both in academia and in the exploding field of battery production, design, assembly and management. Moreover, the PhD student will develop valuable skills for the emerging field of <i>in operando</i> battery studies, aimed at next-generation monitoring based on transduced quantities beyond electrical and thermal.
Composition of the research group	1 Full Professors 2 Associated Professors 0 Assistant Professors 4 PhD Students
Name of the research directors	Prof. Benedetto Bozzini

Contacts
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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
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 3.000,00. 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.

Computer availability: individual use.

Desk availability: individual use.

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 Steering Committee.