POLITECNICO DI MILANO

PhD in SCIENZE E TECNOLOGIE ENERGETICHE E NUCLEARI / ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY - 38th cycle

PNRR_352 Research Field: ANALYSIS OF BATTERY AGEING

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. This requirement is specially crucial for stationary storage. Performance decay is caused by a range of entangled and poorly understood 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 - causing electrode poisoning - and current-collector corrosion. Finally, mechanical failure of the electrode and loss of electric contact can yield electrochemically inactive areas. These issue are attacked with both modelling an experimental approaches.The modelling side in most cases relies on integral approaches and transfer-function methods with limited or no material-relevant input. As far as experimental methods are concerned, 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 for societally crucial fields, such as stationary electrochemical energy storage in support of the implementation of renewable energy sources, fully in line with the topics targeted by DM n.352 (09/04/2022), Art.s 1.7 and 6.4a, specifically "Green revolution and energy transition". This scenario motivates doctoral research on the degradation of battery materials and the corresponding modelling, 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 *post mortem* analyses of single cells, both of laboratory and commercial scales. The cells will be aged with electrochemical protocols, 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 X-ray computed tomography, 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 materials-science tools, such as tomography, surface-sensitive spectoscopies, 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 the space organization. The third stage of the study will be devoted to the development of *in situ* and *in operando* imaing 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. 6 months of training at NHOA Energy S.r.l., Milan, will be a specific qualifying educational objective of this PhD project.
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 or 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.
Composition of the research group	1 Full Professors 2 Associated Professors 0 Assistant Professors 6 PhD Students
Name of the research directors	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	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	NHOA Energy S.r.l. Piazzale Lodi 3 ¿ 20137 Milano
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Helmholtzstraße 8, 89081, Ulm, Germany
By number of months abroad	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 forparticipation in courses, summer schools, workshops and conferences, instrumentations andcomputer, etc. The amount is about Euro 5700.

Teaching assistantship: Availability of funding in recognition of supporting teaching activities by the PhD student. Thereare various forms of financial aid for activities of support to the teaching practice. The PhDstudent is encouraged to take part in these activities, within the limits allowed by the regulations.

Computer availability: individual use.

Desk availability: individual use. Accommodation in Politecnico's Residences (http://www.residenze.polimi.it) is available for PhDcandidates; special rates will be applied to selected out-of-town candidates(detailed info in the call for application).

Research period abroad: Our candidates are strongly encouraged (6 months minimum is mandatory) to spend a research period abroad, joining high-level, research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 700 euro/month- net amount).