POLITECNICO DI MILANO

PhD in FISICA / PHYSICS - 38th cycle

PARTENARIATO PNRR Research Field: HERSEM - DEVELOPMENT AND VALIDATION OF HYDROGEN INCLUSIVE ELECTRONIC, CHEMICAL AND STRUCTURAL NANOSCALE IMAGING BY HIGH ENERGY RESOLUTION SCANNING ELECTRON MICROSCOPY

Monthly net income of PhDscholarship (max 36 months)
€ 1300.0 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	The PNRR project - Spoke 9 - NEST, **CUP D43C22003090001 D.D. 1561 del 11/10/2022.** Catalyzers are at frontier of the search for renewable energy due to the role they can play in many steps of the circular chain, from solar energy collection in biological and biomimetic systems, to energy storage and conversion to and from chemically based accumulators. The need for large surface-to-volume ratio in catalysts is driving the evolution of meso-structured, nano-structured and porous materials exploited in the energy chain. Due to this trend, a strong and urgent demand for high resolution material imaging and analytical techniques is raised from the energy sector. These techniques should be able to rapidly address nanoscale size point of interest from wafer-wide view fields, and to obtain electronic, chemical, and structural information at their best spatial resolution. Particularly challenging is addressing light element, down to hydrogen, and their compounds. They play key roles in the renewable energy cycle, although today's analytical mapping techniques hits several limits in the investigation of light element related properties. Transmission electron microscopy (TEM) is at present one of the most performing analytical tools. It achieves better than atomic lateral resolution with probes such as X-ray fluorescence, cathodoluminescence (CL), Electron Energy Loss Spectroscopy (EELS) and electron diffraction. TEM is however limited in its view field and requires a cumbersome sample preparation. Due to these

	requires a cumbersome sample preparation. Due to these limitations, points of interest in specimens showing stochastic properties, like catalyzer in polycrystalline or powder form are hardly identified in situ by TEM. On the other side, the lateral resolution of optical techniques is limited by diffraction to 100s nm at best. This includes Raman and FTIR spectroscopies (and their evolutions bases on coherent stimulation) that join imaging abilities to high structural and chemical selectivity and hold the capability of rapidly switching from large to small fields of view.
Methods and techniques that will be developed and used to carry out the research	Scanning electron microscopes (SEM) are widespread tabletop characterization and quality control tools, providing imaging capabilities in the nm lateral scale. X-rays spectroscopy add-ons can be added to SEM to provide compositional mapping at the µm scale, by element selective imaging for element heavier than boron (B). SEMs still lack the easy access to chemical and collective phenomena (plasmonic, phononic) information that is provided by optical microscopes and TEMs with spectroscopic capabilities. Providing chemical and collective phenomena selectivity by sub-electronvolt electron spectroscopic mapping down to the lightest and crucial element, hydrogen, with lateral nanoscale and atomic depth resolution, would make SEMs as the dream tool for the nondestructive investigation of real size application ready system.This PhD thesis will contribute to the development of high energy resolution spectral imaging by SEM (HER-SEM) of the back scattered primary electrons (BSE) and of secondary electrons (SE) emitted by the samples, with the potential of providing elementally and chemically selective information at nm lateral scale and atomic depth scale. This technique would break the diffraction limit typical of far field optical microscopy (hundreds nm), while at the same time providing access to the large field of view (hundreds to thousands mm).The HER-SEM project must face two main challenges. First, the design and implementation of a prototype, joining a sub-eV energy spread electron column working down to few kinetic energy range with a high acceptance sub-eV energy analyzer. Due to the low

	electron escape depth at few kinetic energy the information will boast high surface sensitivity; consequently, the analytical chamber needs ultra-high vacuum (UHV) base pressure to preserve and control the sample surface from the pollution by residual gases. Second, the kind and quality of the analytical capabilities of HER-SEM will need experimental and theoretical validation: prototypical physical and chemical systems will be characterized, and the results compared with experimental literature and ab-initio modeling. After commissioning of the apparatus and of the experimental procedure, catalytical systems for energy application will be investigated, to provide a first original test bed of the technique.The PhD student will deal with these challenges in the framework of a collaboration between the Dipartimento di Fisica at PoliMi (EMlab group) in collaboration with other international leading institutions in electron microscopy like the National University of Singapore NUS, TUDelft in the Netherlands and ISI in Brno, Czech Republic, to name the most concerned.
Educational objectives	Understanding of the principles of electron spectro-microscopy, apparatus design and commissioning. Experimental frontier investigation of nanostructured materials involved in ground-breaking technological and physical condensed matter problems. Participation and presentations at local and international workshops and conferences. Writing of scientific articles and proposals.
Job opportunities	Former PhD students of the group are now following their career in research and academic teaching in electron microscopy, quantum science and condensed matter, as well as in the industry and in consultancy in technology related fields.
Composition of the research group	0 Full Professors 3 Associated Professors 0 Assistant Professors 4 PhD Students
Name of the research directors	Alberto Tagliaferri

Contacts
alberto.tagliaferri@polimi.it

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	650.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Educational activities: 1.766,75 euros per student for each year.

Teaching assistantship:There are various forms of financial grant for activities in support to the teaching practice.The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

Computer and desk availability: Individual use.

Other Information:
The student may access preferential fees depending on her/his family income (ISEE. Indicatore della Situazione Economica Equivalente) at PoliMi’s student residential facilities.