



PhD in FISICA / PHYSICS - 38th cycle

PARTENARIATO PNRR Research Field: ULTRAFINE GROWTH AND ADVANCED SPECTROSCOPY OF CHALCOGENIDES AND 2D MATERIALS FOR SPIN-ORBITRONICS

Monthly net income of PhDscholarship (max 36 months)

€ 1350.0

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 PhD student will have the opportunity to work in the framework of the Research Infrastructure "Nano foundries and fine analysis - digital infrastructure (NFFA-DI)" project [area ESFRI "Physical Science and Engineering" (cod.IR0000015)]. The project is built around a valuable Italian consortium and aims to develop an integrated network for atomically controlled growth, structural and spectroscopic characterization of advanced quantum materials and nanostructures. The activity of the student will focus on materials whose peculiar electronic band structure hold potential for crucial advances in electronics. Thin and ultrathin films of chalcogenides (such as germanium telluride and its alloys, bismuth telluride, and others) will be the starting base of the research activity. Chalcogenides are of large interest nowadays in the scientific community as new substrates to keep the Moore's law alive. Exemplarily, compounds belonging to the class of ferroelectric Rashba semiconductors, such as GeTe [1], are widely investigated thanks to their unique ability to control the band structure and therefore the transport properties with the ferroelectric polarization [2]. Their investigation requires the fine control of the growth conditions, and at the same time a fine characterization of electronic structure (also in-operando) and transport properties. In the **NFFA-DI project**, a rather unique laboratory cluster tool for molecular beam epitaxy (MBE) and in-situ angle resolved photoemission spectroscopy (ARPES) will be installed at Polifab. The Ph.D. student will participate in the installation and commissioning of this laboratory. The in-house research during the



	<p>commissioning and upskill phase will be focusing in particular on the mapping of the band dispersion of high-quality crystalline films of advanced spin-orbit materials (as in [3, 4]), with a significant impact expected on the scientific community. In the last period of the PhD she/he will be also involved in experiments proposed by users of the NFFA-DI infrastructure.</p> <p>CUP: CUP B53C22004310006 - D.D. 3264 del 28/12/2021</p> <p>[1] R. Bertacco <i>et al.</i>, Adv. Mater. 25, 509 (2013), doi: 10.1002/adma.201203199. [2] R. Bertacco <i>et al.</i>, Nature Electronics 4, 740 (2021), doi: 10.1038/s41928-021-00653-2. [3] R. Bertacco <i>et al.</i>, Nano Letters 18, 2751 (2018), doi: 10.1021/acs.nanolett.7b04829. [4] R. Bertacco <i>et al.</i>, Adv. Mater. 28, 560 (2016), doi: 10.1002/adma.201503459 .</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>The Ph.D. candidate will carry out the following activities:</p> <ul style="list-style-type: none"> -Deposition of chalcogenides films and other selected materials on 2-inches substrates by a state-of-the-art MBE tool; - In-situ characterization of the as-grown samples by angular resolved UV photoemission spectroscopy (ARPES) and other surface-sensitive X-ray and electron-based spectroscopic and diffraction techniques (XPS, XPD, LEED, RHEED), all in-situ available at Polifab; -Study of the band-structure versus external stimuli (in-operando measurements versus applied voltage, laser light, etc.) in thin films and microstructures. <p>The Ph.D. student will have the opportunity to participate in the installation and commissioning of the MBE and ARPES machines, acquired within the NFFA-DI project. Collaboration with the other partners of the project will be fundamental to ensure steep advancement in the scientific knowledge associated to spin-orbit materials. In particular, the Ph.D. student will take advantage of the synergy with the group of Prof. Giorgio Rossi and Giancarlo</p>



	Panaccione, leaders in the spectroscopy of solids through X-ray photoemission and working at the Italian synchrotron facility Elettra – APE beamline.
Educational objectives	<ul style="list-style-type: none"> - Development of interdisciplinary knowledge at the boundary between physics and electronics. - Expertise in the growth of chalcogenides by molecular beam epitaxy. - Advanced knowledge in the spectroscopy of solids. - Basic/intermediate knowledge in device fabrication.
Job opportunities	<p>This activity will be carried out mainly at Polifab, the micro and nano technology center of the Politecnico di Milano, and part of the Joint Research Center of STMicroelectronics and Politecnico di Milano (STEAM). The Ph.D. student will have the opportunity to do a period abroad, especially at synchrotron radiation facilities within and outside the project network, to acquire specific know-how or to access other facilities functional to the research project. The NFFA-DI project is based on a wide consortium, with several groups spread on the Italian area, such as CNR, Elettra (Trieste) and UniMI (Milano). The wide know-how acquired during the doctorate will give to the student a solid basis for future carrier development, in academia or in semiconductor industry.</p>
Composition of the research group	1 Full Professors 2 Associated Professors 1 Assistant Professors 2 PhD Students
Name of the research directors	Bertacco

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	675.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>Educational activities per year : Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per 3 years: max 5.503,32 euros per student.</p> <p>Teaching assistantship: 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.</p> <p>Computer availability: individual use</p> <p>Desk availability: individual use</p>