UNIVERSITÀ DI PARMA

Dottorato di Ricerca in Fisica - XXXVII ciclo – PhD in Physics

In the application for the competitive examination, the candidate must elaborate a short project on one of the research topics listed below (only the topic indicated as first choice in the application).

1. Lab-on-Chip technology for predictive maintenance in green energy production field

The activity aims to design and develop Lab-on-Chip systems for real-time analysis of lubricating oils in order to minimize waste, environmental impact and maximize the efficiency of green energy plants, such as wind and hydroelectric plants. Lab-on-chip (LOC) systems are miniaturized devices able to integrate multiple functions or analysis techniques conventionally conducted in laboratories by specialized operators [1][2]. In other words, LOC devices can be defined as small laboratories built on portable chips that can perform multiple laboratory analyzes on fluid samples [3].

These systems are based on optical and spectroscopic techniques such as:

1) UV / Vis, NIR, MIR spectroscopy [4][5]
2) Label-free and fluorescent dye based spectrofluorimetry [6]
3) Microscopy and particle tracking methodology [7] for the characterization of micro and nano-debris in solution using Cloud or on-the-edge AI algorithms.

The project focuses on topics oriented to technologies for smart grids, renewable sources, and distributed generation. In fact, thanks to innovative Industrial Internet of Things (IIoT) technologies, it is possible to avoid unexpected machine downtime, production losses, breakdowns due to poor maintenance and overestimated oil changes that cause high environmental impact. In addition, it allows to maximize productivity and to have control about the state and maintenance of energy plants, with particular attention to wind power plants where, having characteristics of randomness, an unexpected breakdown/maintenance causes even more damage.

The planned activity will be carried out in close collaboration with the company, where will be guaranteed a one-year period of activity in which the doctorate student will work in a dynamic environment with a high innovative and technological content. On this matter, SanChip has also been the winner of several Innovation Awards both at national and regional level including the Start Cup Emilia-Romagna 2020 and two special Marzotto's awards. Mainly the activity will focus on research and development programs and the candidate will have the opportunity to work inside the company laboratory equipped with various advanced

instruments and in which both the design and prototyping of LOC devices and sensitive components integration activities are carried out.

References

[1] "Increased Flexibility in Lab-on-Chip Design with a Polymer Patchwork Approach" D Pezzuoli, E Angeli, D Repetto, P Guida, G Firpo, L Repetto, Nanomaterials 9 (12), 1678

[2] "Micro and nanofluidic platforms for advanced diagnostics" E Angeli, V Mussi, P Fanzio, C Manneschi, L Repetto, G Firpo, P Guida, U.Valbusa (2014) Edorium J Nanotechnol 1, 1-7

[3] "Nanofluidic-Based Accumulation of Antigens for Miniaturized Immunoassay" D Pezzuoli, E Angeli, D Repetto, F Ferrera, P Guida, G Firpo, L Repetto Sensors 20 (6), 1615

[4] "Simultaneous monitoring of multiple quality parameters of lubricating oils by Vis-NIR spectroscopy" A. Kadekin, E. Hagemann, D.R. Staveren – Tribologie Schmierungstechnik 65 Jahrgang (2018)

[5] "Determining the Kinematic Viscosity of Lubricant Oils for Gear Motors by Using the Near Infrared Spectroscopy (NIRS) and the Wavelength Selection" Ricardo Henrique de Paula Pedroza, Jábine Talitta Nunes Nicácio, Bruno Souza dos Santos & Kássio Michell Gomes de Lima Analytical Letters (2013)

[6] "On the use of intrinsic fluorescence emission ratio in the characterization of hydraulic oil degradation" C. Ossia, H. Kong, L. Markova, N. K. Myshkin Tribology International (2008)

[7] "Simultaneous Electro-Optical Tracking for Nanoparticle Recognition and Counting" E.Angeli, A.Volpe, P. Fanzio, L.Repetto, G. Firpo, P.Guida, R. Lo Savio, M. Wanunu, U.Valbusa (2015) NanoLetters Vol.15 n.9

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2. Systems for large-scale electrical energy-storage with low environmental impact deriving from pyrolysis of biomass waste

Efficient storage of electrical energy for large-scale applications is one of the major needs of the near future. Lithium ion batteries represent the state of the art of current technology, however their use on a large scale poses serious sustainability and disposal problems. On the contrary, supercapacitors represent an emerging green technology, which promises to help, or even replace, current batteries for large-scale stationary storage applications, for example in smart grids for renewable energy, with considerably low environment impact, if not zero. The candidate will explore novel carbon nanostructures obtained from biomass pyrolysis as porous electrodes for innovative biocompatible and cost-effective supercapacitors. Part of the activity will be spent within the company Henesis S.r.l., of the Camlin group (www.camlingroup.com), a leader in the energy and environment sector.

References:

- F. Beguins, et al. “Carbons and electrolytes for advanced supercapacitors”, Adv. Mater. 26, 2219-2251 (2014)
- K. Qian, et al. “Recent advances in utilization of biochar”, Renew. Sus. Energ. Rev. 42, 1055-1064 (2015)
- D. Pontiroli, et al. “Super-activated biochar from poultry litter for high-performance supercapacitors”, Microporous Mesoporous Mater. 285, 161-169 (2019)

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3. Towards a new generation of transistors for low-loss power electronics: development of novel materials and devices.

Power electronic sectors such as automotive, PV inverters, electrical line hubs etc., require more efficient converters with low losses. Energy losses are especially pronounced during the on-off transients of the power transistors utilized in converter fabrication. We therefore need new generations of semiconductors, capable of working at higher voltages, reducing losses, and producing a positive impact on environment and climate. Semiconducting oxides are very promising in this sense, in particular Gallium Oxide (Ga2O3) [1]. Thanks to the very high breakdown voltage and Baliga figure of merit, they exhibit higher performance than traditional Silicon or other high bandgap compound semiconductors such as GaN and SiC.

The synthesis and study of gallium oxide was started by the proposing group a few years ago [2] and is currently focused on the epsilon phase [3]. The planned activity for the PhD student will concern, in the initial phase, the development of Schottky diodes, in vertical and/or lateral geometry, and subsequent extension to field effect transistors (FET), including the preparation of the material and the study of its physical properties, device design and simulation, prototype fabrication. These phases of the PhD work will be carried out in collaboration with national and international partners. A semester in a leading company in the field of electronic materials and a period abroad are foreseen.

[1] M. Wong and M. Higashiwaki “Vertical beta power transistors: a review”, IEEE Trans. Electron. Dev. 67 (2020) 9198897

[2] F. Boschi, M. Bosi, T. Berzina, E. Buffagni, C. Ferrari, R. Fornari: “Hetero-epitaxy of ε-Ga2O3 layers by MOCVD and ALD”, J. Crystal Growth 443 (2016) 25

[3] A. Parisini, A. Bosio, V. Montedoro, A. Gorreri, A. Lamperti, M. Bosi, G. Garulli, S. Vantaggio, R. Fornari: “Si and Sn doping of ϵ-Ga2O3 layers”, APL Mater. 7 (2019) 031114

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