LMGP
Laboratoire des matériaux et du génie physique
une vision des matériaux

Grenoble INP

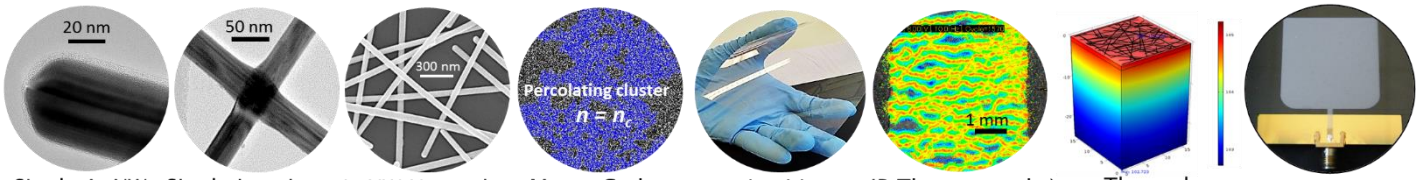
cnrs

2016-2017

Internship proposal (Master or final project engineering school) at LMGP

Flexible Transparent Electrodes based on Silver Nanowire Networks: Electrical Percolation, Mechanical Properties, Integration into Radio Frequency devices

Transparent electrodes attract intense attention in many technological fields, including solar cells, OLEDs, touch screens, transparent film heaters and electromagnetic (EM) devices. New generation transparent electrodes are expected to have three main physical properties: high electrical conductivity, high transparency and mechanical flexibility. The most efficient and widely used transparent conducting material is currently indium tin oxide (ITO). However the scarcity of indium associated with ITO's lack of flexibility and the relatively high manufacturing costs have prompted a search into alternative materials. With their outstanding electrical and optical properties [1,2], silver nanowire (AgNW)-based percolating networks appear to be one of the most promising alternatives to ITO for plenty of applications [3].



Single AgNW (TEM) | Single Junction (TEM) | AgNW Network (SEM) | Monte Carlo Simulation | Flexible Material | IR Thermography) | Thermal Simualtion | AgNW based Antenna

The goal of this internship is to better understand and optimize the electrical and mechanical properties of such networks, and to test their performance, in EM devices. The approach could be, depending on the skills/wishes of the trainee, based on:

(i) Fundamental aspects
- → Fabricating architectures of AgNW networks using Matlab-based Monte-Carlo simulations.
- → Revealing the electrical and thermal maps of AgNW networks using Comsol-based finite element method.
- → Physical modelling.

(ii) Experimental approach
- → Fabrication of AgNW networks on bendable plastic substrate (PEN) and stretchable substrates (PDMS).
- → Deep study of the mechanical properties of AgNW networks (ultimate bending, stretching, and twisting capability)
- → Impact of the size effects (diameter and length of the nanowires) on the mechanical (and electrical) properties.

(iii) Integration into devices
- → Fabrication of large scale bendable and/or stretchable AgNW electrodes dedicated to electromagnetic shielding.
- → Impact of bending and stretching on the shielding effectiveness.

This internship offers a good trade-off between fundamental and experimental aspects. The candidate will get precious knowledge and skills in physics and nanomaterial sciences. The LMGP houses state of the art experimental equipment to fabricate Ag nanowire networks with in-situ electrical resistance measurement set-up [4,5,6]. A bending set-up is also available and should be updated for making possible the stretching and bending tests. A special attention will also be devoted to the stability of the obtained transparent electrodes and the integration of these transparent electrodes into devices will be performed. Simple models as well as numerical simulations (based for instance on stick percolation) will be developed to better understand the physical properties.

Related references:

[1] D.P. Langley, G. Giusti, C. Mayousse, C. Celle, D. Bellet, J.-P. Simonato, ***Nanotechnology*** 24 (2013) 452001;
[2] S. Sorel, D. Bellet, J. N. Coleman ***ACS Nano*** 8 (2014) 4805;
[3] T. Sannicolo, M. Lagrange, A. Cabos, C. Celle, J.-P. Simonato, D. Bellet, ***Small***, DOI: 10.1002/smll.201602581, (2016);
[4] D.P. Langley, M. Lagrange, G. Giusti, C. Jimenez, Y. Bréchet, N.D. Nguyen, D. Bellet, ***Nanoscale*** 6 (2014) 16535;
[5] M. Lagrange, D.P. Langley, G. Giusti, C. Jimenez, Y. Bréchet, D. Bellet, ***Nanoscale*** 7 (2015) 17410-17423.
[6] T. Sannicolo, D. Muñoz-Rojas, N. Nguyen, S. Moreau, C. Celle, Caroline, J.P. Simonato, Y. Bréchet, D. Bellet, ***Nano Letters*** 16 (2016) 7046-7053

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Scientific environment: Located in the heart of an exceptional scientific environment, the LMGP offers the applicant a rewarding place to work. The applicant will be integrated within a close collaboration between several scientists of LMGP, CEA, and IMEP-LaHC laboratories.

Laboratory website: http://www.lmgp.grenoble-inp.fr/

Profile: We are looking for a highly motivated student who is interested to work in an inter-disciplinary project. Interpersonal skills, dynamism, rigor and teamwork abilities will be appreciated. Candidates can be fluent either in English and/or in French
Subject could be continued with a **PhD thesis** : Yes/~~No~~.
Stipend: an internship stipend will be provided (554€/month)

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