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

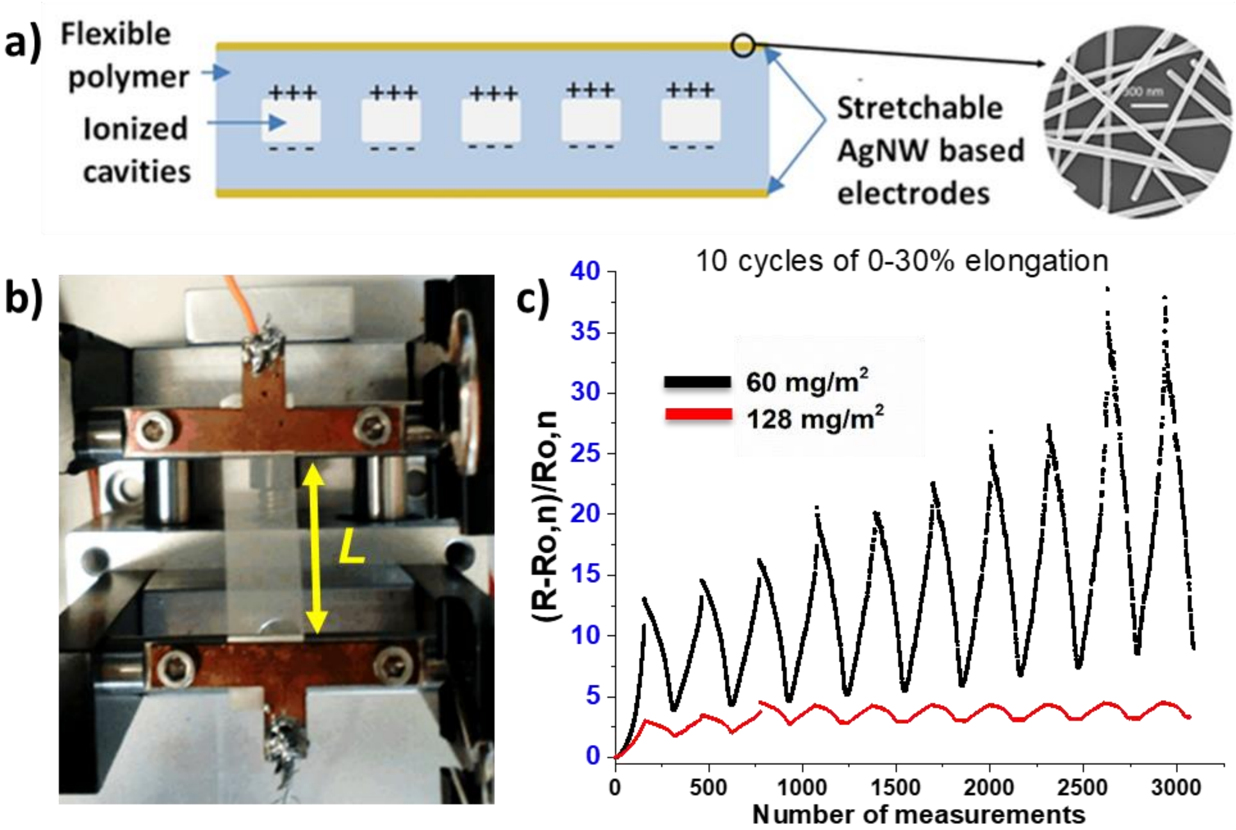
UGA Université Grenoble Alpes · Grenoble INP · cnrs

2020-2021

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

Transparent and flexible electrodes based on silver nanowire networks: Fundamental properties, stability and integration into energy harvesting devices

Transparent electrodes attract intense attention in many technological fields, including solar cells, OLEDs, touch screens, transparent film heaters. New generation transparent electrodes are expected to have three main physical properties: high electrical conductivity, high optical 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, silver nanowire (AgNW)-based percolating networks appear to be one of the most promising alternatives to ITO for plenty of applications [1,2,3]. Although the properties of these transparent electrodes are already remarkable, many problems remain to be understood, such as the network defects, the electrical homogeneity and their stability [4,5].



Today, embedded sensors have gained in precision, reliability, robustness and miniaturization; they are widely used in the Internet of Things. As well developing energy generators that convert ambient mechanical energy into electricity is an innovative challenge to make these sensors autonomous; this would significantly reduce the environment of such sensors and/or reduce their energy consumption. In this context and in the framework of project *Carnot Energies du Futur*, LMGP and two other laboratories at Grenoble (G2Elab and TIMA) **are collaborating to develop flexible energy generators** designed from electro-active elastomers, based on the deformation of materials incorporated between two deformable electrodes and operating in an electrostatic mode (see schematic figure a). LMGP is focusing on the flexible electrode which should withstand rather large mechanical deformation while remaining conductive. While the commonly used electrodes with conductive pastes appear rather fragile, a promising alternative solution concerns electrodes based on AgNW. The partners LMGP and G2ELAB/TIMA have independently developed specific expertise on stable and efficient electrodes based on AgNW (LMGP) and flexible electrostatic generators (G2Elab/TIMA); the combination of these three laboratories will allow a good synergy to obtain efficient and durable electrostatic generators whose integration will easily be the object of collaborations with the industrial sector.

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The actions carried out in this internship concern the development of materials for the fabrication of these flexible generators, their characterization and their physical modelling. This internship offers a good trade-off between fundamental and experimental aspects, coupling experiments and modelling to better understand the fundamental and physical phenomena concerning the degradation of AgNW networks under electrical and thermal stress. The candidate will get precious knowledge and skills in physics, nanomaterial sciences and energy harvesting systems as well. The LMGP houses state of the art experimental equipment to fabricate AgNW networks and several in-situ electrical resistance measurement set-up (like the bending-stretching apparatus in figure b) [4-7]. The optimization of the stretchable electrodes fabrication and the control of their electrical properties under mechanical stress (figure c) is critical for an efficient integration in this type of energy harvesters.

Related references:

[1] D.P. Langley, G. Giusti, C. Mayousse, C. Celle, D. Bellet, J.-P. Simonato, ***Nanotechnology*** 24 (2013) 452001

[2] T. Sannicolo, M. Lagrange, A. Cabos, C. Celle, J.-P. Simonato, D. Bellet, ***Small***, 12 (2016) 6052-6075

[3] D. T. Papanastasiou, A. Schultheiss, D. Muñoz-Rojas, C. Celle, A. Carella, J.-P. Simonato, D. Bellet, ***Advanced Functional Materials*** (2020), *30*, 1910225.

[4] T. Sannicolo, N. Charvin, L. Flandin, S. Kraus, D. T. Papanastasiou, C. Celle, J. Simonato, D. M. Rojas, C. Jiménez, D. Bellet, ***ACS Nano*** (2018), 12, 4648

[5] A. Khan, V. H. Nguyen, D. Muñoz-Rojas, S. Aghazadehchors, C. Jiménez, N. D. Nguyen, D. Bellet, ***ACS Appl. Mater. Interfaces*** (2018), 10, 19208–19217.

[6] M. Lagrange, D.P. Langley, G. Giusti, C. Jimenez, Y. Bréchet, D. Bellet, ***Nanoscale*** 7 (2015) 17410-17423.

[7] 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

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

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 (≈600€/month for a training longer than 10 weeks)

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