

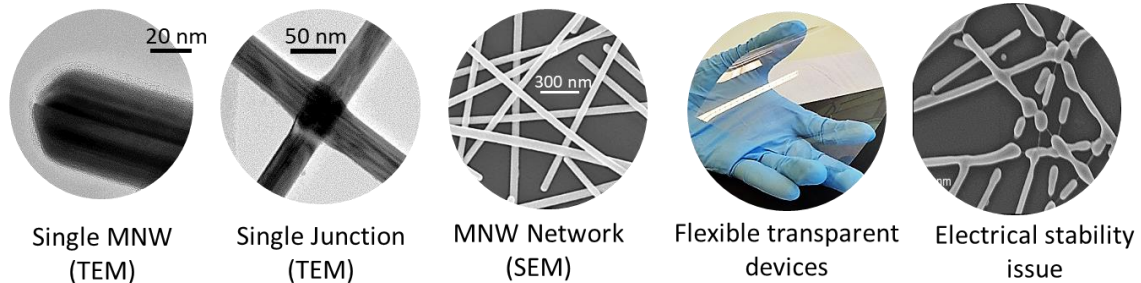
2020-2021

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

### Transparent Electrodes based on Silver Nanowire Networks:

#### Fundamental properties, stability and integration into 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 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].



**The goal of this internship** is to couple experiments and modelling to deeply understand the physical phenomena occurring at the scales of the network and also at the nanowire junctions aiming for integration of these electrodes in optoelectronic devices.

The approach could be, depending on the skills/wishes of the trainee, based on:

(i) Fundamental aspects

→ Understanding and physical modelling of the mechanisms between AgNWs when we spray some water droplets on AgNW networks. This leads to an electrical resistance reduction. This is called “capillary force-induced cold welding”.

(ii) Experimental approach

→ Deposition of AgNWs by spray-coating technique on glass and flexible/bendable plastic substrates (PET, PEN, PEDDOT)  
→ Optimization of AgNW networks through cold-welding post-deposition treatment  
→ Enhancement of electrical and thermal stability of AgNW networks with the development of nanocomposites such as AgNWs and conformal oxide layers by Spatial Atomic Layer Deposition (ZnO has been tested but SnO<sub>2</sub> still remains a rather innovative way)

(iii) Integration into devices

→ Integration of these transparent electrodes for solar cell and transparent heater applications.

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 Laboratoire des Matériaux et du Génie Physique (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 special attention will also be devoted to the optimization and stability enhancement of the obtained transparent electrodes and the integration of these transparent electrodes into devices will be performed. For instance we have shown in the lab that the conformal coating of AgNW by thin oxide layers leads to a much enhanced stability [7,8,9]. Simple models as well as numerical simulations will be developed to better understand the physical properties.

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**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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