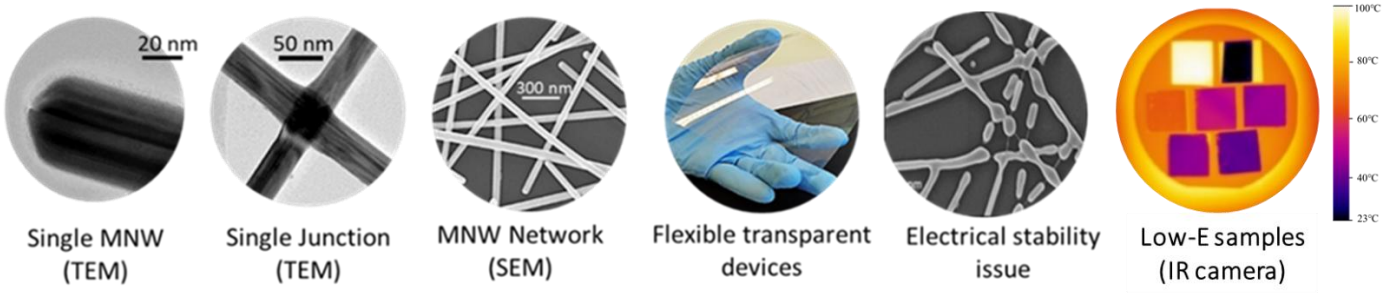
2025-2026

Internship proposal (Master 2, final project engineering school) at LMGP

Investigation of silver nanowire (AgNW) networks: improving their physical properties and stability for efficient integration into devices

Silver nanowire (AgNW) networks, are known for being efficient transparent electrodes. Their optical transparency, good electrical properties and mechanical resilience, offer a sustainable solution for many applications, such as solar cells, transparent heaters[1], low-emissivity films[2,3] etc. These networks can be produced at a large scale, making them suitable for widespread implementation[4,5]. Although the properties of these transparent electrodes are already remarkable, many problems remain to be understood, such as the relationship between electrical and optical properties, the influence of network defects, the electrical homogeneity and their stability[6–9]. Silver nanowire networks can be deposited onto various surface textures and substrates, enhancing their versatility[10].



Electronic or optical pictures of AgNW networks at different and key length scales, up to the device applications

The goal of this internship is to better understand and optimize properties and stability of AgNW networks, aiming for integration of these electrodes in solar cells or low-emissivity coatings. The focus will be on both experimental and (possibly) simple physical modelling approaches. For instance, by studying the dependence of infrared (IR) emissivity of silver nanowire networks with their network density, we found that the percolation threshold does not appear at the same value when compared with the electrical percolation threshold. This recent observation, called dual percolation in material science, is of clear interest and would of high interest to be further observed and understood.

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

(i) **Experimental approaches**

→ Deposition of AgNWs by spray-coating technique on glass and flexible/bendable polymeric substrates

→ Observation of the optical transmittance, IR-emissivity and sheet resistance of AgNW networks

(ii) **Fundamental aspects**

→ Better understanding of the physical properties thanks to **simple physical modelling;** namely we would like to better understand the relationship between the optical transmittance, the IR-emissivity of AgNW networks and electrical resistance. We could as well start using non-pure AgNW (originated from recycled Ag stemming from old solar panels) and other metallic nanostructures (such as core-shell nanowires, Cu@Ni nanowires for instance). These nanowires would be provided by collaborators from Grenoble (CEA) or Bordeaux (ICMCB).

(iii) **Integration into devices**

→ Integration as transparent electrodes in efficient state-of-the-art solar cells as well as low-emissivity films, for energy saving, thermal management and/or computer reservoir.

This internship offers a good trade-off between fundamental, experimental and applied aspects. The candidate will get precious knowledge and skills in physics and nanomaterial sciences. The Laboratoire des Matériaux et du Génie Physique (LMGP), located at Grenoble, houses state of the art experimental equipment to fabricate Ag nanowire

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networks with many characterization tools (such as UV-VIS-NIR spectrophotometer, IR-camera, electronic microscopes, X-Ray Diffraction…) and including also in-situ electrical resistance measurement set-up[11]. 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 in devices[2,12]. Moreover we have shown at LMGP that the conformal coating of AgNW by thin oxide layers leads to a much enhanced stability[13,14], but the effects of such coatings on IR-emissivity of AgNW networks are still unexplored. Simple physical models can also be developed to better understand the physical properties and stability enhancement[10].

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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 (CEA, SIMAP, LTM at Grenoble, ICMCB in Bordeaux and Physics Department in Liège University).

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 should be fluent in English.

Stipend: an internship stipend will be provided (≈600€/month for a training longer than 10 weeks)

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