**Flexible Transparent Electrodes based on Silver Nanowire Networks: Nanoscale Characterisation, Electrical Percolation, and Integration into Devices**

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The most efficient and widely used transparent conducting material (TCM) is currently indium tin oxide (ITO). However the indium scarcity associated to the lack of flexibility of ITO as well as relatively high cost of fabrication has prompted the search for alternative low cost and flexible materials. Among emerging transparent electrodes (TEs), silver nanowire (AgNW) networks appear as a promising substitute to ITO since these percolating networks exhibit high flexibility and excellent optoelectronic properties [1], with sheet resistance of a few Ω/sq and optical transparency of 90%, fulfilling the requirements for many applications such as solar cells, OLED displays, transparent heaters, or radio-frequency (RF) antennas and transparent shielding [2]. In addition, the fabrication of these electrodes involves low-temperature process steps and upscaling methods, thus making them very appropriate for future use as TE for flexible devices.

Our research is focused on the fundamental understanding of the physical phenomena taking place at the scales of both the network (macroscale) and the NW-to-NW junctions (nanoscale), and on the ability of AgNW networks to be integrated as transparent electrodes for flexible optoelectronic and RF devices. In-situ electrical measurements performed during optimisation process such as thermal annealing and/or chemical treatments provide useful information regarding the activation process of the junctions [3]. Besides, nano-characterisation techniques such as Transmission Electron Microscopy (TEM) and ultramicrotomy help visualizing the physical phenomena involved in the diffusion of silver atoms to create well-sintered junctions. At the network's scale, our ability to distinguish the nanowires taking part in the electrical conduction (“electrical percolating pathways”) from the inactive nanowires is a critical issue for the applications. By combining experimental and simulation studies, a discrete activation process of efficient percolating pathways through the network was evidenced. In the case where the network density is close to the percolation threshold and when low voltage is applied, individual “illuminated” pathways can be detected through the network while new branches get activated as soon as the voltage is increased.

Here we will present our results on the study of AgNW networks at the macro and nano scales described above and will correlate it with the overall performance/characteristics of the networks. We will also present results on the integration of optimized AgNW networks into functional devices.


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

[2] C. Celle, C. Mayousse, E. Moreau, H. Basti, A. Carella and J.-P. Simonato, Nano Res. 5, 427, (2012).

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