Travail de Fin d'Etudes : Optical and electrical properties of metallic nanostructures as electrode material for wide bandgap semiconducting junctions

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Optical and Electrical Properties of Metallic Nanostructures as Electrode Material for Wide Band Gap Semiconducting Junctions

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Keywords: Transparent electrode (TE), silver nanowire network (AgNW), spin coating, transparent conductive oxide (TCO), cuprous oxide (Cu_2O), sputtering, annealing, scanning electron microscopy (SEM), spectrophotometer, sheet resistance

Optoelectronic components are made of active layers sandwiched between two electrodes. The challenge in developing transparent devices is to combine optical transparency and electrical conductivity, since highly transparent materials (glass, plastic) are insulating, while highly electrically conducting materials (silver, gold) are opaque. We fabricated a transparent electrode made of a silver nanowire network and relied on a wide band gap semiconductor (Cu_2O and Cu_2O:Mg) to make the p-type layer of a pn-junction. The goal was to test the compatibility between the silver nanowire network and the underlying cuprous oxide thin film.

After testing a dynamic and a static spin coating method, depending on whether the substrate was rotating during the dispensing of a solution of silver nanowires, we concluded from SEM images that the dynamic method resulted in the most uniform distribution of nanowires and the largest nanowire network density. Based on optical and electrical characterizations using a spectrophotometer and resistance measurements, we showed that our transparent electrodes, fabricated on glass substrates, were able to compete with other transparent electrodes mentioned in the literature.

When applying the same dynamic deposition process on Cu_2O films obtained by RF magnetron sputtering, adhesion problems between the silver nanowires and the underlying layer arose. We suggest that the wetting properties and the roughness of the substrate influence the quality of the network. Another issue was encountered when the nanowires were annealed at 250°C. This post-deposition process is necessary to decrease the junction resistance between nanowires, but was responsible for the decomposition of the thinnest nanowires. These problems have not been encountered for silver nanowire networks deposited on magnesium-doped cuprous oxide, for which a good conducting electrode has been obtained.

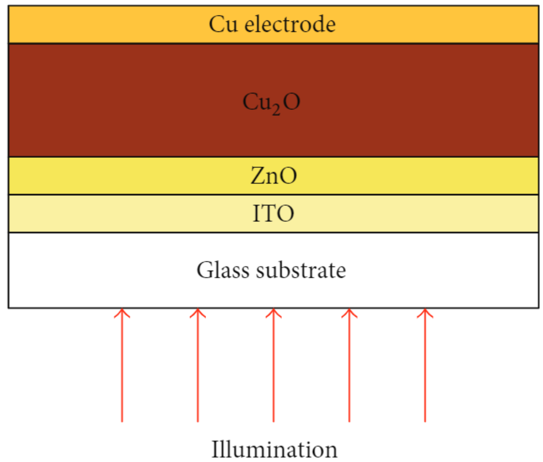

Figure 1: Schematic of the structure of a solar cell. The goal of this thesis was to fabricate the Cu_2O layer by magnetron sputtering and to replace the opaque copper electrode by a transparent network of silver nanowires.

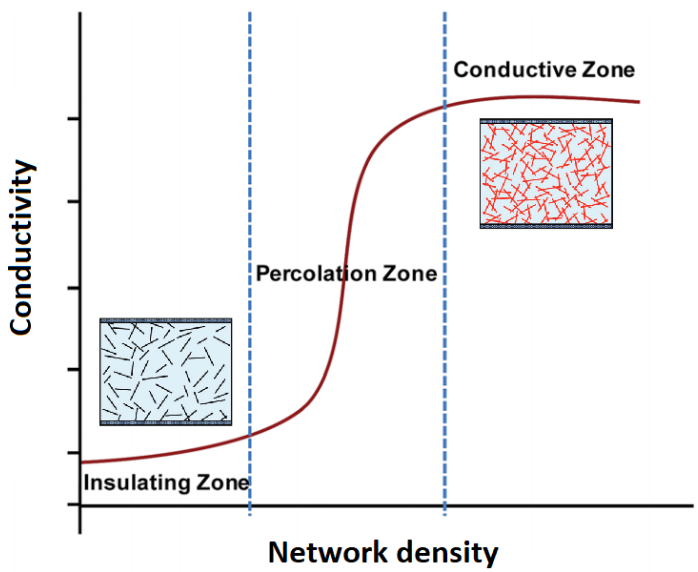

Figure 2: Illustration of the evolution of the conductivity as a function of the nanowire network density. The transition between the insulating zone and the percolation zone depends on the critical density, governed by the length of the nanowires.

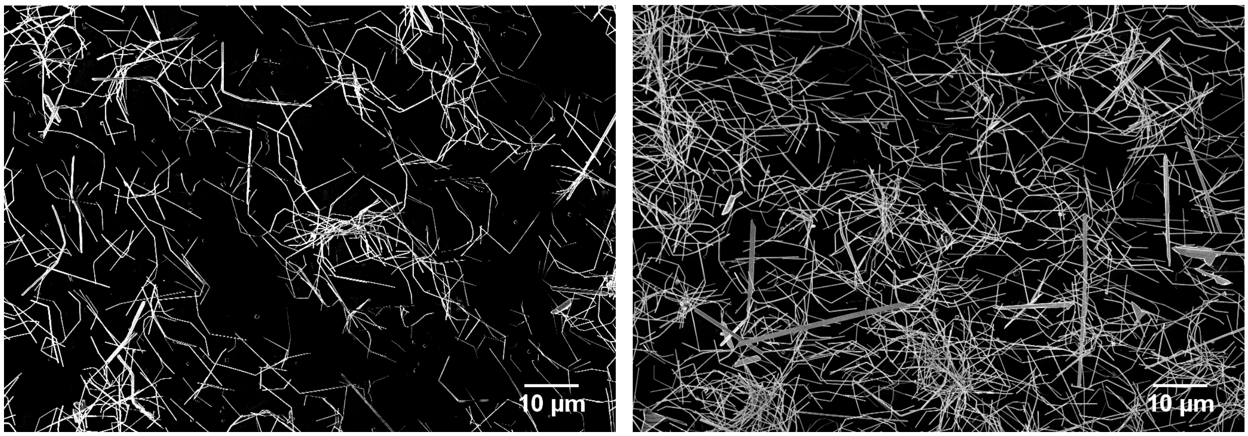

Figure 3: SEM image comparison between static (left) and dynamic (right) spin coating. The dynamic deposition method results in a denser nanowire network. A dense network offers a better electrical conductivity, but a decrease in optical transmittance.

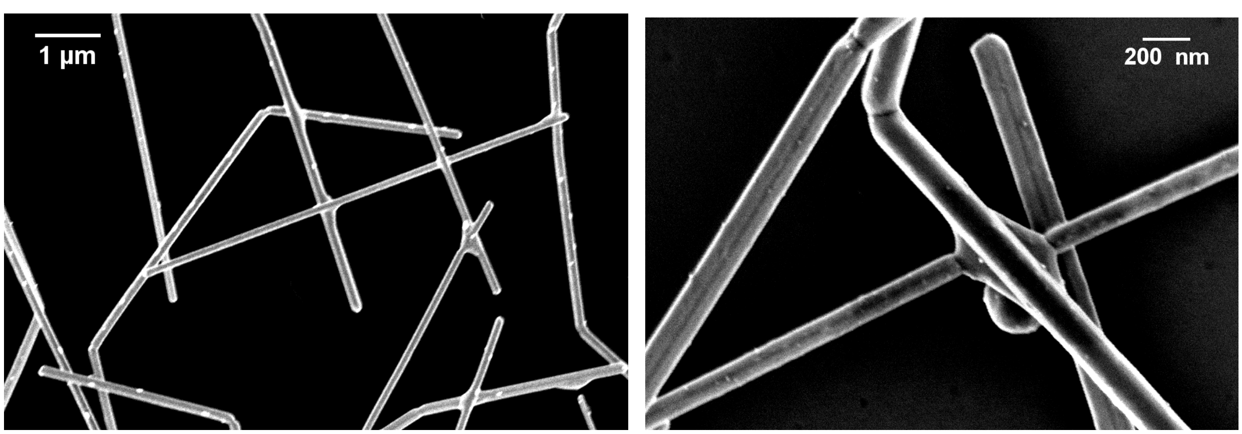

Figure 4: SEM images showing the welding of silver nanowires after annealing at 250°C. Thermal annealing after spin coating is necessary to decrease the junction resistance and render the network conductive.

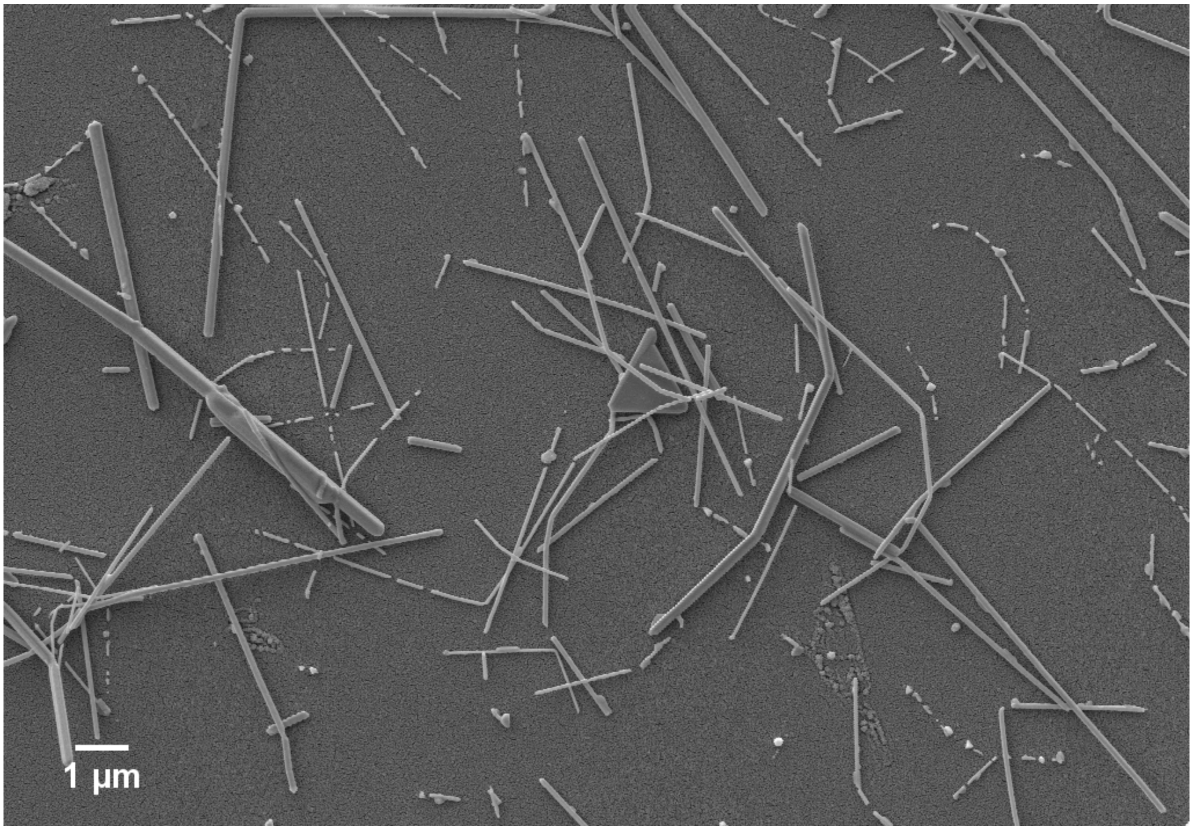

Figure 5: SEM image of the thermal decomposition of silver nanowires deposited on Cu_2O and annealed at 250°C. According to Rayleigh-Plateau, only the thinnest nanowires become unstable and spheroidize.

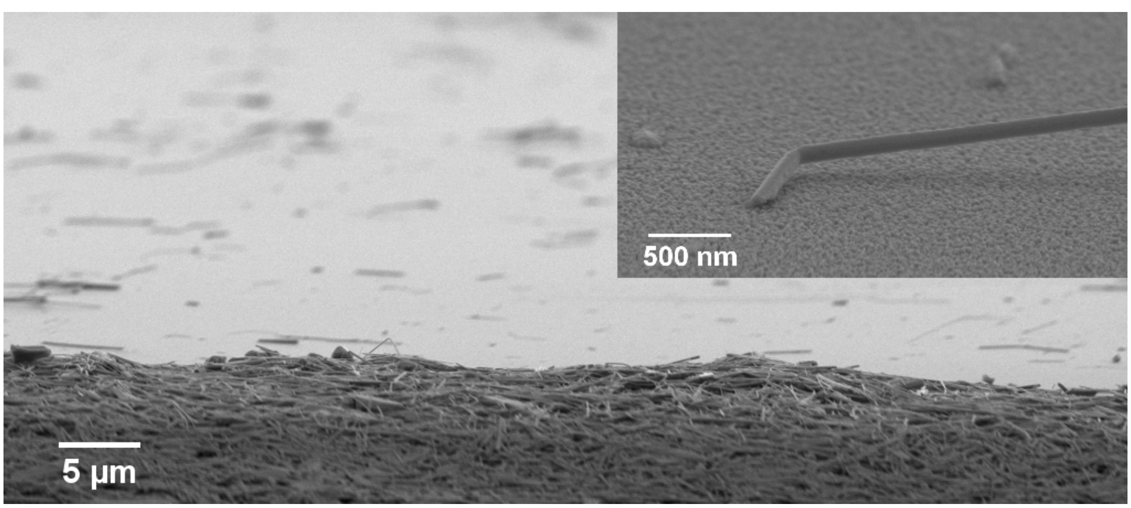

Figure 6: SEM images of silver nanowires deposited on Cu_2O and annealed at 280°C. The large figure shows that silver nanowires accumulate at the borders of the sample, while the inset illustrates the bad adhesion of silver nanowires with the underlying Cu_2O thin film.