Ultrathin Au nanowires : towards 1D electronic properties

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Abstract

Recently, ultrathin gold nanowires (NWs) prepared by reduction of HAuCl4 in solution of oleylamine (OY) attracted lots of interest due to their size homogeneity (diameter 1.7 nm, micrometer length) [1] with application as foldable optoelectronics membranes [2,3] or elastic coiled springs [4]. Their unique 1D feature confers them remarkable conductivity properties such as quantum phenomena at room temperature [5,6] but the study of the electronic properties of single NW still remains a technological challenge and requires a good understanding of their physical properties.
SAXS (Small Angle X Ray Scattering) and XPS studies allowed us to describe the self-assembly of ultrathin Au NWs into an expended hexagonal super-lattice with a parameter of 9.7 nm well explained by a oleylammonium chloride (OY+ Cl-) / oleylamine (OY) bilayer at the surface of each NW and suggests a 1D micellar growth mechanism [7]. To confirm this hypothesis, SANS (Small Angle Neutron Scattering) and NMR studies have been recently performed.
We showed that Au NWs solubilized in hexane exhibit a net negative charge in presence of strong electric field, due to the reorganization of the OY+ Cl- ions. Thus, the design of predefined positive patterns using AFM nanoxerography, enabled us to deposit isolated Au NWs thanks to a Coulomb force directed assembly. The stability of single Au NWs under external stimuli was studied in-situ by real-time HAADF-STEM [8]. Under electron beam irradiation, Au NWs tend to fragment into stable islands through the ejection of atoms and the appearance of quantized atomic channels as transient state. Modification of the wire surface energy, through ligands exchange process, could enable to further stabilize the single-atom thick chains, opening great perspective for further electronic transport measurement on isolated Au NWs deposited by nanoxerography.

References

[1] H. Feng et. al, Chem. Comm., 1984 (2009)
[2] Y. Chen et al., Adv. Mater. **25** (2013) 80
[3] A. Sanchez-Iglesias et al., Nano Lett. **12** (2012) 6066
[4] J. Xu et al. J. Am. Chem. Soc. **132** (2010) 11920
[5] S. Pud et al. Small, **9** (2013) 846
[6] A. Loubat et al. Nano Res., **6** (2013) 644
[7] A. Loubat et al. Langmuir, **30** (2014) 4005
[8] L.-M. Lacroix, A. Arenal, G. Viau, J. Am. Chem. Soc., **136** (2014) 13075

Figures

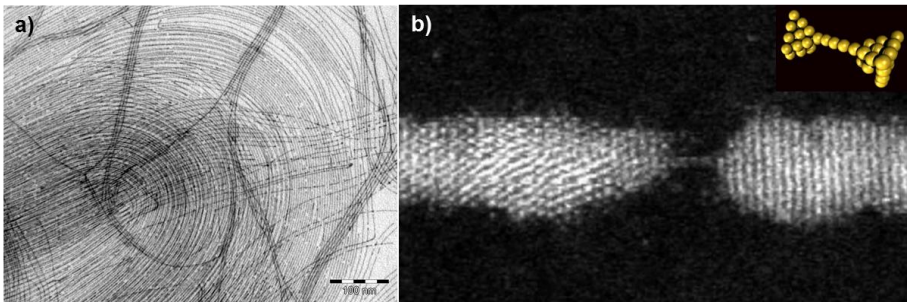

Figure 1. a) TEM and b) HAADF-STEM images of Au NWs. Single-atom thick chain formed during wire fragmentation under E-beam irradiation.