Ultrathin gold nanowires as self-organizing inks for printed electronics

Lola Gonzalez-Garcia*, Johannes H.M. Maurer, Beate Reiser, Dominik Gerstner, Ioannis Kanelidis and Tobias Kraus

INM – Leibniz Institute for New Materials, Saarbrücken, Germany

**e-mail: lola.gonzalez-garcia@leibniz-inm.de*

We study transparent conductive materials (TCMs) based on metal nanoparticles (NPs) that combine high electrical conductivity with optical transparency and mechanical flexibility. Metal nanowires networks deposited via wet processing are considered promising candidates for a new generation of transparent electrodes from relatively cost-effective, scalable production. Random networks require high wire densities to reach percolation and conductivity, which reduces the transparency of the final material. We develop wet deposition methods that reduce the required densities by forming TCMs with defined microstructures.
Ultrathin gold nanowires (AuNWs) exhibit diameters below 2 nm and lengths in the micrometre range (Figure 1a). Their mechanical flexibility and large conductivity make them interesting candidates for their application in printing electronics. AuNWs can be synthesized in a facile and scalable one-pot synthesis at room temperature that yields a stable dispersion using oleylamine (OAm) as capping ligand [1]. They show uncommon agglomeration behaviour and form bundles (Figure 1b) with hexagonal lattices due to OAm-OAm interactions [2]. AuNW layers reach competitive conductivity values after soft sintering in plasma [3]. Wire bundles are sintered into stable, conductive structures as shown in Figure 1c.
Our approach is based on the self-assembly of AuNWs into superstructures as a bottom-up route to well-defined wires networks. We exploit the AuNWs' unusual colloidal behaviour to create self-organizing inks for printed electronics in two different deposition routes that create conductive paths: (a) direct nanoimprinting of AuNWs inks that self-organize into percolating networks even at low gold concentrations [4], and (b) flow extrusion of the bundling AuNW into continuous lines. Both methods are compatible with industrial productions and roll-to-roll processes.

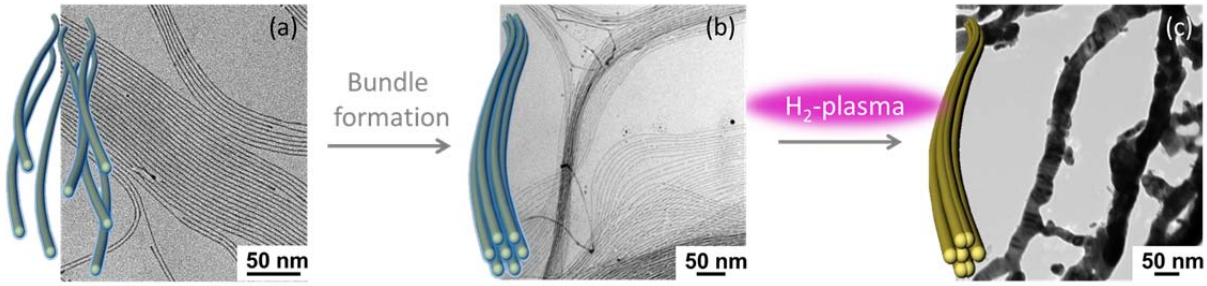

Figure 1. Transmission electron micrographies and schemes of ultrathin gold nanowires (a), AuNWs forming a bundle (b), and gold structure formed after plasma treatment (c).

[1] H. Feng et al., *Chem. Comm.,* 2009, 1984.
[2] A. Loubat et al., *Langmuir,* 2014, **30**, 4005.
[3] J.H.M. Maurer et al., *Appl. Mater. Interfaces,* 2015, **7**, 7838.
[4] J.H.M. Maurer et al., *Nano Lett.,* 2016, DOI: 10.1021/acs.nanolett.5b04319.