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Effect of molecular layers on charge transport in nanowires

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Abstract. Stable ultrathin gold nanowires (Au NWs, 2nm diameter) were produced using wet chemical synthesis, which implied oleylamine molecules, and subsequently assembled onto gold electrodes. Transport properties of fabricated structures were studied using the noise spectroscopy technique. Lorentzian-shaped components were revealed in the noise spectra. The characteristic frequencies of these components were independent of the bias applied, which thus excludes self-heating of the nanowires. Noise peculiarities were shown to be the result of the presence of oleylamine molecules on the NWs. The evidence of oleylamine on the surface of the fabricated structures was confirmed by high-resolution transmission electron microscopy. Organic monolayers can strongly influence charge properties in nanosystems. These results should be taken into account in designing nanowire-based devices for molecular electronics.

1. Introduction

Ultrathin metal and semiconductor nanowires are attractive objects for investigations due to their unique properties[1] and wide range of possible applications[2,3]. Nanowires possess high surface-to-volume ratio, which makes them suitable for (bio)sensing applications. Metal NWs may be used as quasi one dimensional conductors for applications in nanoscale electronics. Studies of charge transport in such nanowires are therefore very important. We produced bundles of stable ultrathin Au NWs with diameters in the range of 2÷5nm and lengths of several microns[1] using wet chemical synthesis. After synthesis, the nanowires were assembled onto large gold electrodes using a microfluidic channel. The detailed sample fabrication procedure is described in Ref. [1]. Due to specific synthesis conditions, oleylamine residuals may remain on the surface of the nanowires.

In this contribution, we investigate the transport properties of ultrathin Au NWs using a low-noise spectroscopy technique. We show that the noise peculiarities revealed are the result of oleylamine influence on charge transport in nanowires.

2. Results and discussion

The normalized current noise spectrum, measured for synthesized ultrathin Au NW, is shown in Fig. 1a. At least two well-resolved Lorentzian-shaped components (at 3 Hz and 58 Hz) were revealed in the noise spectra. Further studies were performed on 2÷5nm Au NW structures without oleylamine. After measurements of bare Au NWs oleylamine molecules were deposited onto the nanowires. The current noise spectral density graphs are shown in Fig. 1b. The noise follows 1/f behavior in the bare metal NWs while several Lorentzian-shaped components can be recognized when oleylamine was deposited on the structure surface. Thus the appearance of Lorentzian-shaped noise components has to be addressed in fluctuation processes due to molecules covering the nanowire surface.

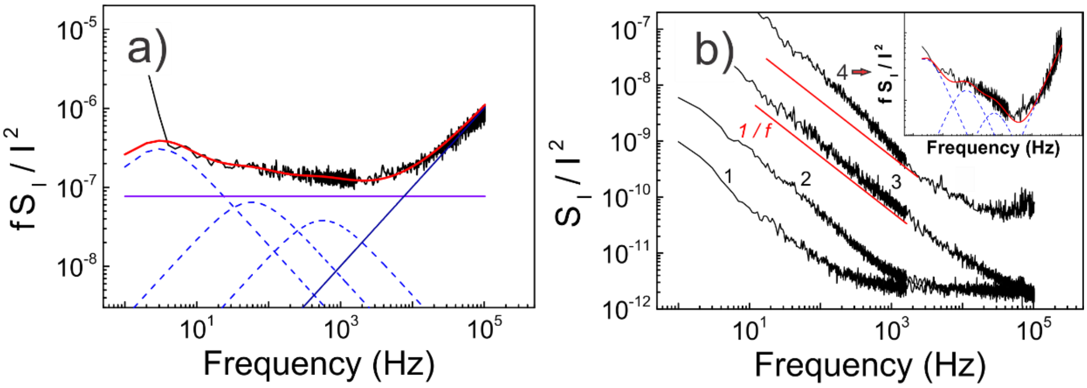

Fig. 1 a) Normalized current noise spectral density, measured for Au NWs with oleylamine molecules; b) Noise spectral density measured for bare Au NWs with diameters in the range of 2 nm to 5 nm (curves 1–3) and for 5 nm diameter Au NW with oleylamine deposited on the nanowire surface (curve 4). For clarity, curve 4 is replotted in the inset. Two well-resolved Lorentzian-shaped components at characteristic frequencies of 3 Hz and 58 Hz are related to molecule-nanowire interactions.

It should be noted that oleylamine was used to assist the growth of Au NWs. After synthesis these molecules may remain on the surface of the nanowires forming an insulating layer between NWs and contacts. Results of transmission electron microscopy confirm the formation of a uniform molecular layer of oleylamine molecules (see Fig. 2).

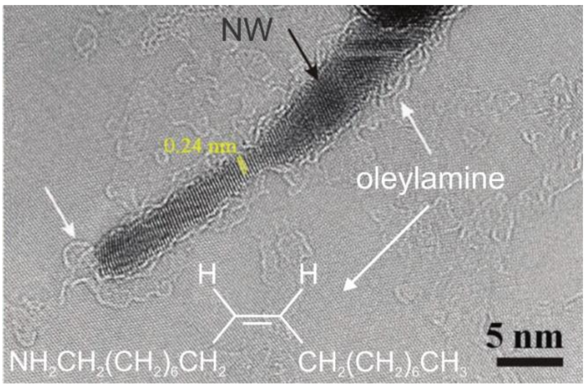

Fig. 2 High-resolution transmission electron micrograph of Au NW on a graphene sheet

The presence of such molecular interfaces influences the dynamics of charge transport in the structures.

3. Summary

To conclude, the presence of monolayers of organic molecules on the surface of nanowire structures influences their transport properties. Noise spectroscopy is a powerful method for studying these layers. The revealed peculiarities should be taken into account in designing NW-based devices for molecular electronics.

References

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