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Use of a nanoelectrode nanoparticle bridge platform in molecular electronics

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A core element of reliable and reproducible measurements in molecular electronics on single and few molecules are measurement platforms with nano-electrode spacings from a some Angstroms up to several tens of nanometers. A number of excellent studies have reached a very good reproducibility in measurements in the last years, though, most of the used platforms are carried out under particular measurement conditions such as vacuum, low temperatures and other special set-up conditions. The purpose with this work is to fabricate and optimise a molecular electronics nanocontact platform suitable for electrical characterization of different molecular systems at ambient conditions. In this work we have coated the nanogaps with both, non-conductive and conductive molecules, respectively and bridged them by dielectrophoretic trapping of gold nanoparticles (GNP) into the electrode gap. We investigate the electrical response of these molecules in this platform. The FIB is the central device in the fabrication of ~10-30 nm nanogaps.[1] Figure 1 shows a wire bonded nanocontact. The empty gap resistance of 1000 TΩ makes these gaps suitable for investigations of high resistance molecules and nanoparticles. We have characterized the FIB cut gap using HRTEM and find that crystalline Au is at the electrode surface. Using this platform, a large numbers of highly reproducible and stable nanogaps can be created. Thus, this lithography based platform can be assessed and optimised systematically. For this purpose, we evaluate this platform using 2 approaches including molecular coating 1) of the electrodes, 2) of the nanoparticles bridging the gap. In the first approach, using octanthiol as a test molecule, we observe resistances of 140GΩ. A typical I-V curve is shown in Fig. 2. The resistance histogram over several devices shows a distribution of the resistance over 2-3 orders of magnitude. Replacing, in approach 1, the monothiol by biphenyldithiol.[2] Therefore, in order to obtain more reproducible measurements, we have developed a method where nanoparticles are functionalised and with alkane-dithiols where the dangling thiol is protected after nanoparticle synthesis, then trapped into the electrode gap. The dangling thiol end binds then to the Au surface after removing the protection molecule. The deprotection leads to a drop in resistance of 2-3 orders of magnitude and resistance histograms that are much narrower. Furthermore, we obtain resistances of octane-dithiol that are comparable to other resistance measurements on this molecule. A comparison of our I-V measurements with simulations of the deprotection process obtained from a density functional theory approach shows a good qualitative agreement between our model and the experimental data. This optimisation enables the use this platform for molecular electronics measurements.

References

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Figure 1a. SEM image of wire bonded gold nanocontact. The inset shows a single trapped gold nanoparticle in the FIB cut gap.

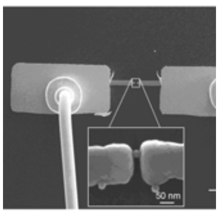

Figure 2. I-V characteristics of a gold nanoparticle (SEM Inset) trapped in between octanethiol coated gold nanoelectrodes