Capillary Assembly and Electrical Characterization of Gold Nanorod Chains as Bottom-Up Electrodes for Molecular Electronics

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**Chains as Bottom-Up Electrodes for Molecular Electronics**

**Capillary Assembly and Electrical Characterization of Gold Nanorod Chains**

**Motivation and Goal**

- The long term vision of molecular electronics is to employ small ensembles or even single molecules as functional building blocks in electronic circuits.
- Attaching molecules to metal surfaces requires “alligator clips”, which enable both a chemical and an electron coupling of the molecule to the electrodes.
- The intrinsic functionality of the molecular building block is implemented in the molecular backbone, defined by the chemical structure of the molecule. For instance, conformational changes of a molecule can change its conductivity. This can be used to create single-molecule switches.

**Goal**

- Gold nanorods represent ideal nanoelectrodes to contact small ensembles of molecules due to their small contact area (diameter < 30nm).
- Chains of gold nanorods can be used to form multiple molecular junctions on a single chip to which a backgate voltage could be applied.

**Capillary Assembly and Printing of Gold Nanorod Chains**

- The master contains protruding structures, which are fabricated by electron-beam lithography with a negative-tone resist (hydrogen silsesquioxane).
- Replication with polydimethylsiloxane (PDMS) produces an inverted pattern of trenches. The width of the trenches was varied by design from 10 nm to 200 nm.
- Nanorod chains are fabricated by capillary assembly. A droplet of the colloidal suspension of gold nanorods is squeezed between a silicon confinement slide and the PDMS template. Nanorods are trapped into the trenches at the contact line of the receding meniscus.
- The nanorod chains are printed onto a pre-structured Si substrate with 30 nm SiO2 using a 50 nm thick poly(methyl methacrylate) (PMMA) adhesion layer.
- The PMMA adhesion layer is removed by O2 plasma etching.
- The nanorod chains are contacted to the leads of the pre-patterned substrate by writing individual electrodes using electron-beam lithography (EBL), metallization and lift-off. Electrical characterization was performed using a three-probe measurement setup.

**Assembly Parameters**

- The width of the trenches and the difference \( \Delta T \) between the temperature of the droplet and the dew temperature of ambient air both influence the yield of capillary assembly (fraction of the trenches occupied by nanorods).
- \( \Delta T \) is optimal above 26°C and is limited by the evaporation of the solvent above 31°C.

**Electrical Characterization of Gold Nanorod Chains**

- After immersion (12 hours) of the nanorod chains in CTAB, the measured current was ±10 pA between -10 and 10 V.
- After immersion (12 hours) of the nanorod chains in OPV5, the current at 10 V increased by two orders of magnitude.
- This indicates that the insulating CTAB was substituted by the conjugated and thus more conductive OPV5.

**Summary and Outlook**

- Gold nanorods are used as electrodes to contact ensembles of molecules.
- The gold nanorods are assembled end-to-end, and printed on a pre-structured Si/O2 substrate.
- Electrical characterization of an insulating and conductive molecule indicates that a true molecular device was fabricated.

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**References**


**Summary**

- Gold nanorods are used as electrodes to contact ensembles of molecules.
- The gold nanorods are assembled end-to-end, and printed on a pre-structured Si/SiO2 substrate.
- Electrical characterization of an insulating and conductive molecule indicates that a true molecular device was fabricated.

**Outlook**

- Further optimization of the assembly to achieve a smaller interparticle distance and more detailed characterization.
- Gate dependant measurements.