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Electroless Au Plating and Scanning Tunneling Spectroscopy toward Molecular-based Devices

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Combination of bottom-up processes with top-down processes is one of the candidates to fabricate molecular-based nanodevices with precise structures in a sub-nanometer scale. For the practical application of molecular-based nanodevices such as single-electron transistors, fabrication techniques with a precise structure, high process yield, and high stability need to be developed.

Chemically synthesized Au nanoparticles are good candidates for Coulomb islands, since the size and shape of these nanoparticles can be controlled with the size distribution of ± 10 %, and the tunneling resistance of a ligand molecule on the Au nanoparticles can be controlled by the length of the ligand molecule. Coulomb blockade of chemically synthesized Au nanoparticles observed by scanning tunneling microscopy (STM) has been reported usually at low temperatures such as 4.2 K and 65 K; however, it has not been demonstrated by STM at room temperature. Here, we demonstrate clear Coulomb blockade behaviors on 1.8-nm Au core nanoparticles at room temperature by STM and scanning tunneling spectroscopy (STS) in double barrier tunneling junctions (DBTJs) consisting of STM-tip/vacuum/Au nanoparticle/self-assembled monolayers (SAMs)/Au(111).

There are many experimental reports on nanogap fabrication techniques such as mechanical break junctions, electromigration, oblique metal evaporation with nanoshadowmasks, EBL, and electrochemical techniques. However, these nanogap techniques have difficulty in fabricating the integrated nanogap electrodes on a sample simultaneously since nanogap electrodes need to be fabricated individually; they show low fabrication yields and instabilities at room temperature. Here, we also demonstrate a process for the fabrication of integrated nanogap electrodes by electroless Au plating with a high process yield using a common medical liquid.

We also fabricate and demonstrate single-electron transistors by combining the electroless plated Au nanogap electrodes and the chemically synthesized Au nanoparticles.

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