IV-F Synthetic Approach Toward Single Molecular Transistors

Organic molecules are promising candidates for nano size transistor in two categories of the electronic devices. One is single electron transistor, in which the molecules are used as discrete charge pools. The merit of using organic molecules in this style of devices is that molecules have precise size with determinate electronic states providing stable electronic properties. The other is single molecular field effect transistor, molecules working as the electronic conductor. In this case, resonant tunneling mechanism is expected to work, and the molecular orbital engineering can be utilized in designing complex electronic circuits. In order to realize these appealing devices, we have been constructing optimized nano electrodes and optimized molecules.

IV-F-1 Synthesis of Novel Ruthenium Complexes Optimized for Molecular Single Electron Transistor

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Single electron transistors utilize the Coulomb blockade phenomena with nano size particles as the charge pool. The blockade energy is definitely determined only by the size of the particles, and in order to possess enough energy to work at room temperature the size should be not more than 1 nm. It is still difficult to make this size of nano particles with perfectly same radius. We hope that by using metal complex molecules as the charge pool bearing definite redox states, the blockade energies are controlled by the redox potentials, which are determined by the molecular structure.

The molecule prepared have ruthenium complex moiety in the center, which is protected by a dendrimer layer. The protecting layer provides the tunneling barrier to prevent direct contact between each molecule and of the molecule with the electrodes. The carboxylic group at the surface of the molecule will work as the anchor to the doped silicon electrodes.

IV-F-2 Preparation of Porphyrin Wires Optimized for Molecular Field Effect Transistors

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Although several reports of “single molecular electronic devices” have already published, no one has succeeded the electronic measurement with observing the molecules between the electrodes. We aimed molecular wires that are visible with atomic force microscopy (AFM) even on the rough surface of the nano gap electrodes.

The molecules prepared are porphyrin derivatives that have two meso aryl groups with dendrimers at three and five positions and two ethynyl groups at the remaining meso positions. Molecular mechanics calculations showed that the diameter of the wire is about 5–6 nm that will be easily observed on the rough surface of the nano gap electrodes.

IV-F-3 Synthesis of Octopus Shaped Self Standing Molecular Jacks

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Thiol (-SH) / gold electrodes are the most often used combination for “single molecular electronics” to connect the molecule to the electrodes. The limitations of this combination are (1) electronic contact of this bond is not ideal and significant electronic barrier exist between the molecule and the electrode, (2) the space per molecule is small and a large number of molecules can be connected even to the nano scale electrodes, which disturb the measurements of single molecule.

We have prepared porphyrin derivatives with four meso aryl groups, whose three and five positions are substituted with long alkyl chains with disulfide groups at the ends. The disulfide groups will work as the anchor of the molecule to fix them to gold electrodes. The diameter of the molecule is about 10 nm. So, if the surface area of the nano electrodes is 30 × 30 nm, only nine molecules can be adsorbed on the surface at the maximum. By introducing rhodium metal in the center of the porphyrin molecule, axial rigands can be connected to the metal that will be the molecular wire standing perpendicularly to the electrode surface.