Multifunction Integrated Macromolecules for Molecular-Scale Electronics

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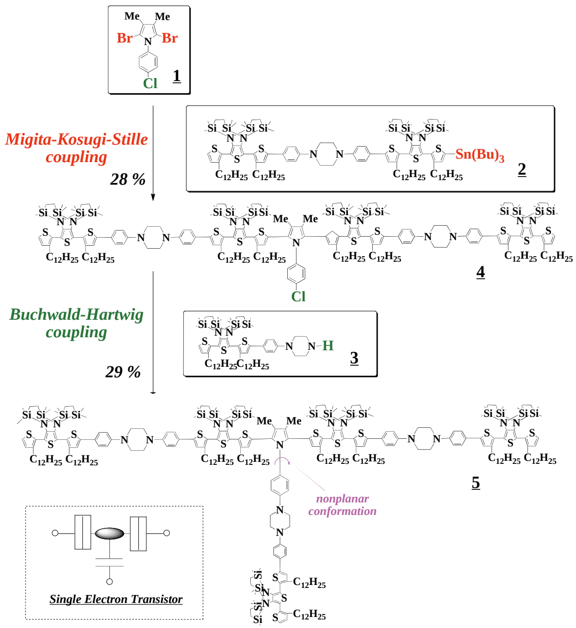
Recently a single electron tunnel (SET) device has attracted much attention due to the growing demand for ultra-low-power device. A SET device manipulates an electron by means of one-by-one electron transfer, resulting in ultimately low power consumption. However, for room temperature operation, the size of SET device must be as small as a few nm to overcome the thermal fluctuation problems. The process size of a few nm is out of the range of conventional micro-technology. In this project, to establish an innovative fabrication process for SET device systems, we have been developing step-wise synthetic protocols for molecule-based single-electron tunnel devices (MOSET) and circuit.



Scheme 1. Step-wise Synthetic Route to Single-electron Transistor.

1. Molecular Design for Mono-Molecular Integration of Basic Components of Single-Electron Devices

Single electron devices comprise three key elements: Coulomb island, tunnel junction, and capacitive junction. To integrate these elements in a single molecule, we have designed versatile molecular building blocks (**1-3**). Using these building blocks, we have synthesized the first trial model of a "mono-molecular" single-electron transistor (Scheme 1). Although there are a lot of issues to be solved, this is the first step to realize the practical MOSET device systems based on mono-molecular integration strategy.

2. Mechanism of Electrical Conduction through Single Oligothiophene Molecules[1)]

The temperature dependence of electrical conductance of oligothiophene molecules with the length of 2.2 nm (5-mer), 5.6 nm (14-mer) and 6.7 nm (17-mer) was measured by break junction method with a scanning tunneling microscope to clarify the charge transport mechanisms. The conductance of 17-mer molecule increased exponentially with temperature whereas the conductance of 5-mer and 14-mer molecules did not change. These results indicate that the dominant charge transport mechanism changed from tunneling to thermally activated hopping at molecular length around 6.7 nm (17-mer).

Reference

1) SK. Lee, R. Yamada, H. Kumazawa, H. Tada and S. Tanaka, *Funct. Mater. Lett.* **3**. 245–248 (2010).