Nanofabrication and Nanomaterial Transport

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A fabrication of a molecular electronics is a recent attractive challenge as next generation nanotechnology. For the realization of molecular electronics, an appropriate molecular selection for functional operation is most important. To achieve a certain electric device function, precise fabrications are needed to approach the molecule intrinsic properties. Especially, the nanometer size electrodes will give us an opportunity to see a nanometer scale material transport.

As an example of our demonstration of the sub-nanometer control fabrication, we proposed a new nanodevice formation in the mutiwalled carbon nanotube (MWNT) of 10 nm in diameter. In the device, the internanotube space was used to form tunnel barrier to make a tunneling device. The internanotube space was 0.34 nm (Fig.1). A schematic cross section of the final structure of the MWNT device was shown in Fig. 2. As the first step, four ohmic Pt/Au electrodes were defined by electron beam lithography on a MWNT. To reduce a junction capacitance of the tunnel device, we carefully disconnected the MWNT layers layer by layer by means of the *electrical degradation method* in the two regions of the electrodes *1–2* and electrodes *3–4* (the outside regions). The disconnection process also gave us information of the total number of the layers contained in the MWNT. There were eight layers. For the tunnel device formation, in the region of electrodes *2–3*, seven layers of the eight layers in the MWNT were carefully disconnected. Only a single nanotube was remained bridging over the two electrodes (Fig. 2).

When the bias voltage was fixed at 5 mV, 7 mV, or 9 mV and the gate voltage was continuously changed, the nonperiodic oscillations of the source-drain current were observed (Fig. 3). These nonperiodic current oscillations can be explained as Coulomb blockade (CB) effect through the multiple tunnel junctions. Because we disconnected seven layers, then, there was a series of 14 tunnel junctions in total. From the observed CB effect, a charging energy was found to be 15 meV, and a total capacitance was deduced to be 11 aF. The tunnel device showed the large charging energy and operated even at high temperature of 4.2 K. The multiple tunnel junctions of 0.34 nm spaces with the small junction capacitances enabled the nanosize tunnel device built in the MWNT to operate even at 4.2 K.

In addition to the nanofabrication in molecule or grain size, we believe that we must address a number of issues: interface control between the molecule and the electrodes, interface control between the molecule and the device substrate, and the intermolecule or molecular-molecular connection. In our presentation, we like to introduce some nanometer scale fabrications, surface control of the electrode, and transport sciences that can be observed only in the nanosize fabricated systems.

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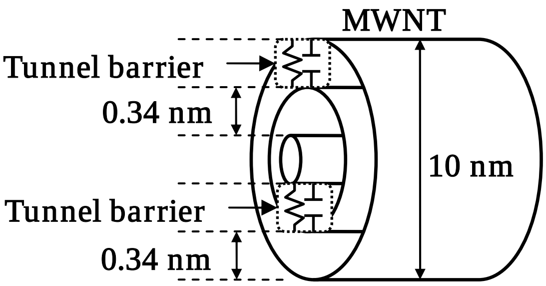

Fig. 1. Schematic view of the inside of MWNT .

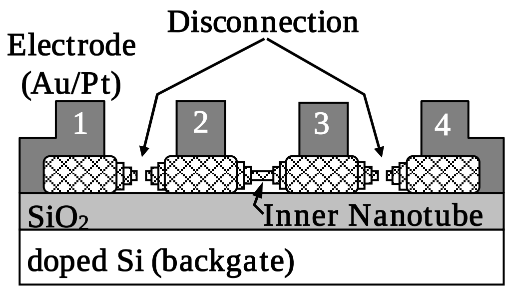

Fig. 2. Schematic cross section of the MWNT device.

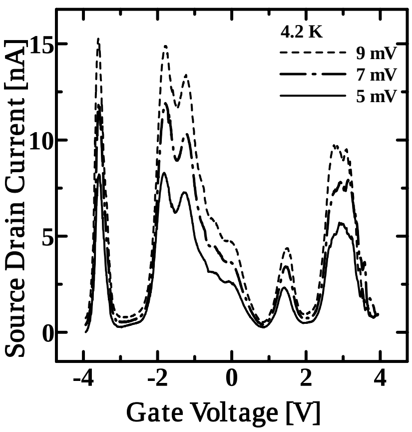

Fig. 3. Source–drain current at the source–drain voltage of 5 mV, 7 mV, and 9 mV at 4.2 K as a function of the gate voltage.