

Device applications of semiconducting single wall carbon nanotubes

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ABSTRACT

Carbon nanotubes are one of the most actively studied materials for nanoscale building blocks in nanotechnology. The unique properties and one-dimensional nature of carbon nanotubes make them potential nanoelectronic devices, chemical and biological sensing elements. We have investigated the effect of contact barrier and humidity on the electrical properties of carbon nanotubes, aiming for the biological sensor applications of carbon nanotube transistors (CNT-FETs).

First, we have immobilized protein-coated nanoparticles at the metal electrode-nanotube contact region. Remarkably, the devices showed a sensitive gate response even with the metallic carbon nanotube. Upon adsorption of the protein-coated nanoparticles at the metal-nanotube contact, the devices fabricated with a metallic single wall carbon nanotube (SWNT) abruptly exhibit a *p*-type transport behavior. In case of the semiconducting SWNT devices, the adsorptions of protein-coated nanoparticles make the gating more effective, resulting in far enhanced device performances such as higher on/off ratios and decreased subthreshold swing. We note that this comes from the sensitive dependence of the contact barrier on the charging states of the proteins, which could be controlled by the gate bias. This switching mechanism could be generalized in the nanoelectronics, relieving a significant effort to separate semiconducting tubes only.

We also investigated the effect of H₂O adsorptions on the electrical transport properties of carbon nanotubes, since it is vital for the biological sensor applications of carbon nanotubes. The adsorption of electron-donating H₂O molecules tend to compensate hole carriers in *p*-type single wall carbon nanotube devices, thereby decreasing the conductance until the relative humidity level reaches 65%. After that, conductance starts to increase again with increasing humidity, due to the opening of electron-conduction channel in carbon nanotube transistors (CNT-FETs). By immobilizing protein molecules on water-saturated CNT-FETs with pyrene linker molecules, we have shown that saturated H₂O molecules hinder the binding of π -stacking molecules. Electronic structure calculations show that when single wall carbon nanotubes were completely covered with H₂O molecules, H₂O molecules tend to form a network among themselves.