Functionalized Carbon Nanotube Sensors for Chemical and Biological Detection

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Presentation

We developed nanoscaled chemical and biological sensors based on functionalized single-walled carbon nanotube field transistors (SWNT-FETs). SWNTs were synthesized via catalytic chemical vapor deposition method. SWNTs were fabricated into field effect transistors (FETs) via electron beam lithography followed by chrome and gold deposition. Only the devices consisted of individual semiconducting SWNT with on/off ratio greater than 1000 were selected for sensing experiments. The SWNT-FET functionalized with short oligonucleotide such as single-stranded DNA was found to be sensitive and selective for a variety of chemical vapors. The SWNT-FET functionalized with human receptor proteins was found to specifically detect the complimentary adenovirus. Our results demonstrated that functionalized SWNT-FETs serve as promising building blocks for manufacturing large arrays of sensitive and specific nanoscaled sensors for chemical analysis and biomedical diagnostics.

Key words: Carbon Nanotubes, Sensors, Field Effect Transistors, Functionalization, DNA, Adenovirus

Abstract: Specific, sensitive, reproducible, and rapid detection of chemical and biological species is crucial for the environment, disease diagnosis, and even homeland security. Owing to the miniature size, large surface to volume ratio, high electrical conductivity, and compatibility with dense array fabrication, carbon nanotubes are excellent candidates for sensing application. In this paper we present nanoscaled chemical and biological sensors based on functionalized single-walled carbon nanotube field effect transistors (SWNT-FETs). The chemical sensor work was done at Prof. A.T. Charlie Johnson's lab at University of Pennsylvania. The biological sensor work was done in collaboration with Dr. J.A. Misewich at Brookhaven National Laboratory, and with Prof. S.S. Wong at Brookhaven State University of New York at Stony Brook. For chemical sensors, single stranded DNA serve as the chemical recognition sites and SWNT-FETs as the electronic readout components. Non-covalent functionalization of SWNT-FETs with DNA resulted in current changes when exposed to gaseous analytes, whereas the bare nanotube devices show no detectable change [1]. The sensor responses differ in sign and magnitude depending both on the type of gaseous analyte and the sequence of DNA being used. DNA functionalized SWNT-FET gas sensors possess rapid recovery and self-regenerating ability, which could lead to realization of large arrays for sensitive electronic olfaction and disease diagnosis [2]. For biological sensors, we present proof-of-concept experiments for developing highly sensitive and fast-response miniaturized SWNT-FET biosensors for electrically detecting adenovirus using ligand-receptor-protein specificity [3]. SWNTs are mildly oxidized to form carboxylic groups on the surfaces without compromising the electronic integrity of the nanotubes. Then the human coxsackievirus and adenovirus receptor (CAR) is covalently functionalized onto the nanotube surface via diimide-activated amidation process. Upon exposure of the device to adenovirus protein, Ad12 Knob (Knob), specific binding of Knob to CAR decreases the current that flows through the SWNT-FET device. For control experiment, the CAR-SWNT device is exposed to YieF, which is a virus protein that does not bind specifically to CAR, and no current change is observed. Our results show that the CAR does immobilize on SWNT surface while fully retains its biological activity. Moreover, the specific binding of CAR to its complementary Knob can be electrically detected using individual SWNT-FET devices. These findings suggest that CAR-functionalized SWNT-FETs can ably serve as biosensors for detection of environmental adenoviruses.

References

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