Nanowire Based Universal Device: Characterization and Bio-Detection

CNF Project # 1469-06

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Abstract:

A nanowire was lithographically fabricated using 50 nm doped polysilicon, attached to small gold terminals separated from each other by 90-150 nm gap. Semiconducting properties and other electrical characteristics of the devices were demonstrated with under varying voltages. Robust bio-molecular detection model were demonstrated on these nano-device using electrochemical impedance spectroscopy (EIS) using pure *Staphylococcus aureus enterotoxin* B (SEB) protein molecules. The lowest detection limit of these molecules was observed in the range of 1-35 fM. These results will lead to the development of a portable detection kit which integrated with digital microelectronics for any biological detection in real time.

Summary of Research:

The development of rapid and ultra-sensitive detection technologies is a long standing goal for researchers in the bio-detection fields. Nanowire based devices [1-5] have shown great promise in label-free and ultra sensitive detection of biological agents. However, critical application problems in using this technology have not been addressed, particularly the difficulties of device sensing surface modification for various targets and lower detection specificity in real biological samples. A novel molecular signal transduction system overcomes such problems. With this system, various complicated bio-molecular interactions are “translated” into simple signal molecules with universal sequences. These signal molecules are captured on the sensing surface of nano-devices through sequence specific recognition and generate detectable electronic signals. Using this system, nano-devices become universal for detecting almost any bio-agents.

In this work, nano-devices were fabricated at the Cornell NanoScale Facility (CNF), Cornell University, Ithaca NY. Four-inch p-type silicon (500 µm)/silicon dioxide (200 nm) wafers were first processed in a polysilicon furnace to deposit 50 nm of a p+ type polysilicon film and later annealed. Desired nanowire structures were obtained by exposing on a Leica VB6 e-beam.

The patterned wafers were then subjected to specific chlorine etches to obtain the desired shape and size for the nanowires. The nanowires ends were then connected with patterned Ti/Au (10 nm / 35 nm) layer leaving 100 nm gap between two electrodes. The outline of fabrication processes and scanning electron microscope (SEM) images of nanowire were depicted in Figure 1. Electrochemical impedance spectroscopy and source meter were used to characterize these nano-device
The sensing surface of the nano-device was modified using a self assembled monolayer on the polyamide surface. These surfaces serve as bonding sites for capture probes, peptide nucleic acid (PNA) or antibodies, to capture specific bio-targets. Nyquist EIS of pure biological protein sample from 1nM to 1fM were used to demonstrate detection on this fabricated nano-device (Figure 4). A clear change in impedance was observed in nyquist semicircle with change in protein conc. demonstrating the device sensitivity to sense any change on its surface due to these protein samples.

We gratefully acknowledge the assistance of Michael Skvarla and Alan Bleier from Cornell NanoScale Facility (CNF). The fabrication work was performed in part at CNF, a member of the National Nanotechnology Infrastructure Network, which is supported by the National Science Foundation (Grant ECS-0335765). This work was supported in part by the USDA grant CSREES 3447917058, NASA grant NNG06GB45G and Hatch grant IDA 00709-STH.

References:

Figure 2: Bode EIS plot of nano-device sensing behavior under varying reference voltages. The spectra clearly showing drop in impedance with increasing voltage suggesting field effect behavior of device.

Figure 3: Electrical characterization of device on source meter: (a) plot of gate voltage ($V_g$) with drain current ($I_d$), graph shows drain current was on around -0.6 V and it was optimum at -5.0 V area. Demonstrates transistor behavior of lithographically defined nano-device; (b) I-V plot of nano-device with -2V to 2V applied gate voltage and 0.0V to 1 V from drain to source terminal. The curve is clearly showing transistor type behavior with p-type channel on the device.

Figure 4: Demonstration of biological detection of protein samples from 1 pM -1 fM concentration on nyquist plot of nano-device showing changes in real and imaginary impedance with increasing conc. of samples.