A Rapid Diagnostic Method to Detect Single Wall Carbon Nanotubes in Nanoscale Windows

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Here we present a diagnostic method to determine the presence of single wall carbon nanotubes (SWNTs) deposited by electrophoresis on metal at the base of a 30-60nm window in an insulating film. Our method allows for rapid diagnostics of invidious devices regardless of their numbers. This is particularly important when the number of devices is over one million. Our method is also scalable to wafer level, as required by mass production for commercialization. We perform our diagnostics by performing current vs voltage (IV) measurements against a single device (which would contain a SWNT in a 30-60nm window) against an external platinum electrode. Both the device and the platinum electrode are immersed in a conductive liquid, such as phosphate buffer. The resulting current would be an indication of the presence of the SWNT. Due to differences in electrodes it is also possible that the IV curves could represent the quality of contact between the SWNT and the electrode that it is deposited on, based on the shape of the curves.

To demonstrate this we performed IV measurement on chips with SWNTs deposited and without. The experimental setup is shown in figure 1. The devices on the chip consist of titanium metal with 75 nm of low stress silicon nitride (SiN_x) deposited on top with 30-60nm windows. SWNTs were deposited in some of the windows using electrophoresis as described by Goyal *et al* (1).

Figure 2 shows IV curves of devices recorded using phosphate buffer solution as the conducting medium to a platinum electrode. The curves are averaged over 12-14 devices. There is a stark contrast in the range of current. Devices without SWNTs have a current range of 100's pico-amps while devices with SWNTs show a current range of a 10's nano-amps. The 2 orders of magnitude difference could be attributed to presence of SWNTs. Another difference in the IV curves are in the shape. Devices without SWNTs exhibited a symmetrical curve but offset such that zero current occurs in the range of -0.2V to -0.47V. The range is from the hysteresis, which is typical in electrochemical systems. Devices with SWNTs also show an offset from -0.2V to -0.32V. In addition the shape of the curve is asymmetrical. With larger currents occurring in the negative voltage region. The differences could be attributed to two factors. One is that without the nanotube the phosphate buffer has to enter a 30-60nm window in SiN_x to reach the Ti metal. The SiN_x layer is hydrophobic making it very difficult for the ions in the solution to react with the Ti metal at the bottom of the windows. This could cause the reduction in current observed without SWNTs. When SWNTs are present, they can extend beyond the SiN_x layer allowing direct access to the phosphate buffer, making the reaction with ions in the solutions significantly easier and allowing higher currents than without SWNTs. The asymmetrical structures of the IV curve with SWNTs are the result of both electrochemical reactions and the contact interface of the nanotube to the Ti metal and will be described in detail.

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1. A. Goyal *et al.* Journal of Vacuum Science and Technology B, 26 (2008) 2524-2528

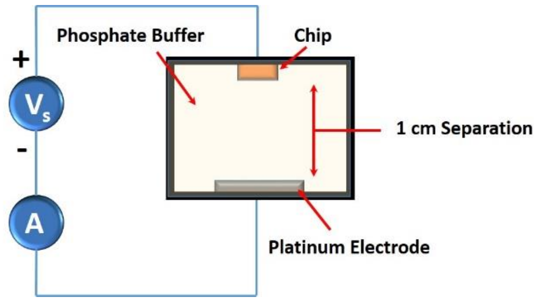

Figure 1 – Schematics of the experimental setup. A HP4140B pico-ammeter was used to apply the external voltage (Vs) and measures the resulting current (A). The chip and the platinum electrode were separated by 1 cm and immersed in a phosphate buffer solution. The chip was connected to the positive terminal and the platinum electrode to the negative terminal.

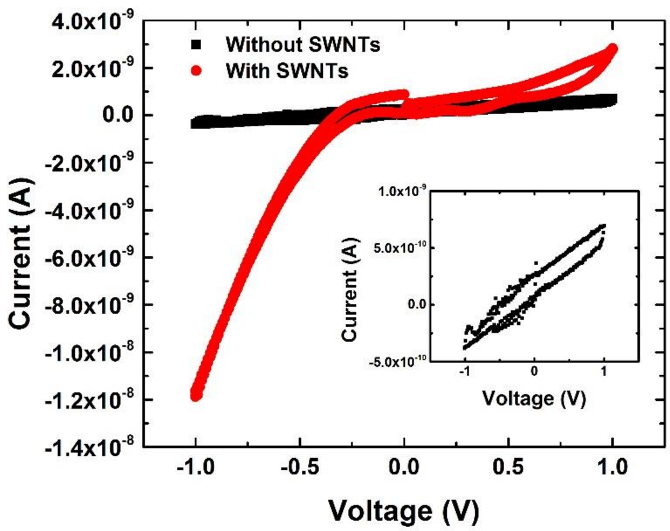

Figure 2 – IV plots of devices with SWNTs (Red Circles) and without SWNTs (Black Squares). The curve for devices without SWNTs is plotted separately in the insert. The plots are average over 12-14 curves. Devices with SWNTs produced up to two order of magnitude higher range of current values with asymmetrical curves. Devices without SWNTs showed more symmetrical IV cures.