Capacitive characterization of the Schottky contact between metal and semiconducting carbon nanotube

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Capacitance-voltage (C-V) measurement is a technique widely used to characterize metal-semiconductor contacts. We apply this technique to measure the capacitance across a back-gated p-type Schottky diode formed by titanium and a semiconducting carbon nanotube, using methods similar to Ashoori[1]. Ohmic and Schottky contacts are made on the nanotube using palladium and titanium, respectively. The results agree qualitatively with simulations done using a Poisson-Schroedinger solver, considering only the electrostatics. The barrier height of the titanium-nanotube contact is measured directly using the C-V measurement, and correlates well with the barrier height extracted from transport measurements. The capacitance across the Schottky contact as a function of the back gate bias is also measured, and shows a strong dependence on the barrier height and the diameter of the nanotube, in disagreement with the electrostatic model alone. The large longitudinal polarizability[2] of the nanotube, neglected in the simulation study, may play a significant role in the details of the contact.

For nanotubes of similar diameters of around 1.8nm, the C-V measurement reveals that the Schottky barrier height (SBH) varies between 60meV and 600meV. The scatter in barrier heights may originate from local variation of the workfunction of the metal grain in direct contact with the nanotube. Metal workfunction is known to depend substantially on the crystal orientation, varying over several hundreds of meV. Since the nanotube diameter is very small in comparison to a typical metal grain, it is possible for the nanotube to make electrical contact to only a specific facet of a single grain. Given that the fermi level at the nanotube-metal contact is unpinned[3,4], the SBH should solely be a function of the metal workfunction for a fixed tube diameter. In Ti, a previous report[5] suggests that the workfunction can vary over 850meV due to crystal orientation alone, in good agreement with the data from the C-V measurement.

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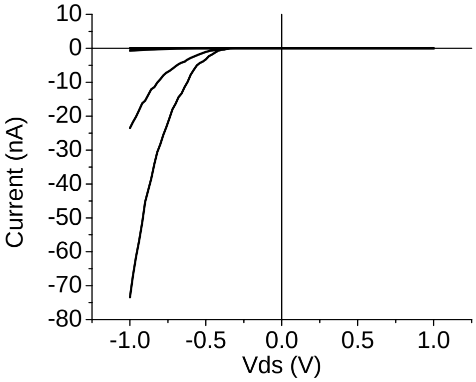

Fig 1: Current-Voltage characteristic of the diode. Vds is applied to the Ti contact while the Pd contact is at 0V. Back gate: -5V to +5V. The largest current corresponds to a back gate of -5V.

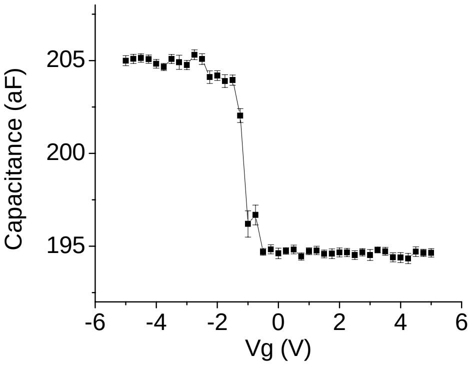

Fig 2: Capacitance vs Back gate voltage Vg. The capacitance between the Ti and Pd contact increases suddenly and saturates at negative Vg, when the nanotube is doped p-type. Measurement frequency: 100kHz.

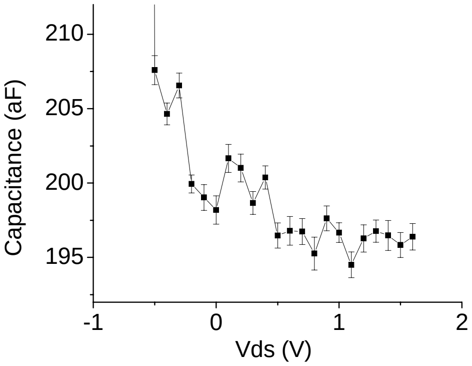

Fig 3: Capacitance vs Vds. The capacitance is seen to increase as the diode is moved from reverse bias to forward bias. Large loss is encountered abruptly at Vds ~-0.5V. The structures in the curve originate possibly from non-monotonic potential profile along the tube due to surface charges on the oxide[6]. Measurement frequency: 100kHz.