Carbon Nanotube Diodes and Transistors with Multiple-Gate Geometry

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Abstract:
Single-walled carbon nanotubes are configured into diodes and transistors with multiple gate geometry. Diodes are fabricated in a split-gate geometry with electron (N) and hole (P) regions separated by a central region that can be gated to be either P, N, or intrinsic. Nearly ideal diode behavior is observed when the central region is intrinsic: the current as a function voltage increases exponentially in forward bias. Carbon nanotube transistors are also fabricated with top gate geometry on high-resistivity silicon substrate. Devices are shown to be operated as microwave mixers up to 50 GHz.

Summary:
Individual semiconducting carbon nanotubes have been shown to make excellent channels for both P and N type field effect transistors (FETs). A P-N interface can be created within single carbon nanotubes through electrostatic gating [1]. By adapting split-gate geometry, we demonstrate the fabrication of nanotubes P-I-N diodes with nearly ideal diode behavior.

In addition, semiconducting carbon nanotubes have been shown to have room temperature carrier mobility exceeding 10000 cm²/Vs [2]. As a result, they offer promise as very high frequency transistors. We fabricate top-gated carbon nanotubes transistors on high-resistivity silicon substrate, and demonstrate that they can function as mixers up to 50 GHz [3].

Our top-gated carbon nanotubes transistors are fabricated on intrinsic silicon substrate (resistivity 12-39 Kohm-cm) with 1 µm thermal oxide. 16 nm SiO₂ is evaporated on the top of nanotubes as dielectrics for the top gate. When operated as a mixer, the nonlinearity of G vs. V results in a DC mixing current proportional to dG/dVg (Figure 2). Despite the attenuation due to the measurement circuit, even at 50 GHz, the mixing signal is nearly identical in shape to the signal at 10 MHz. This means that the nanotube device still operates as a mixer at 50 GHz. Further study of eliminating parasitic capacitances from the setup is currently undergoing in order to explore the intrinsic high-frequency limit of carbon nanotubes.

References:
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Figure 1, above: Carbon nanotube P-I-N diode with split-gate device geometry.

Figure 2, right: Carbon nanotube top-gated transistor working as mixer up to 50 GHz.