Carbon Nanotube Electronics

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Carbon nanotubes (CNTs) can be used to build field effect transistors (CNTFETs). Early devices had marginal characteristics due to their large contact resistances. By improving the contacts and utilizing top-gates with thin oxides, we produced CNFETs with characteristics better than those of silicon devices. CNTFETs with as-grown CNTs are invariably p-type. We discuss two methods for p-to-n conversion: a) doping of p-type devices, b) annealing in vacuum to remove adsorbed oxygen. A comparison of these methods shows fundamental differences in the mechanisms of p-to-n- conversion. The key effect of oxygen adsorption is not to dope the tubes, but to modify the barriers at the contacts. A method for controlling these contact barriers will be demonstrated. Having both p-type and n-type CNTFETs we were able to fabricate complementary logic gates. Two types of NOT gates will be presented: an inter-molecular and an intra-molecular. Finally, we will discuss the fabrication of CNTFETs using CNTs bundles containing both metallic and semiconducting CNTs without first removing the metallic nanotubes.