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Electrical Contacts in Carbon Nanotube Transistors[1]

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Electrical properties of low-dimensional devices are dominated by the contact resistance. For carbon nanotube field effect transistors (CNT-FETs), as for graphene and MoS_2 transistors, the electrical contacts are a key factor limiting device performance. Contact resistance reflects a complex interplay of many factors. With advances in scaling, the contact resistance and transfer length are becoming even more critical. We have developed a general purpose CNT device simulator which is unique in including quantum-mechanical tunneling, both acoustic and optical-phonon scattering, as well as the crucial transfer of carriers between the CNT and metal contact. To illustrate the unique capabilities relative to existing approaches such as non-equilibrium Green's function (NEGF) formalism, we predict the scaling of on-state current with contact length. The behavior is surprising. The transfer length is roughly a factor of two shorter at a typical drain voltage than at low bias. This reflects the onset of optical-phonon scattering underneath the metal contact for a ballistic channel. As we change the nanotube diameter (i.e. bandgap) and metal workfunction a Schottky to ohmic crossover in device characteristics takes place. Although the on-state current varies continuously, the transfer characteristics reveal a relatively abrupt crossover from Schottky to ohmic contacts [1]. The typical high-performance devices fall surprisingly close to the crossover. Therefore, tunneling plays an important role even in this regime, so that current fails to saturate with gate voltage as was expected due to "source exhaustion".

[1] V. Perebeinos, J. Tersoff, W. Haensch, Phys. Rev. Lett. (in press).

[1]This work is collaboration with Jerry Tersoff and Wilfried Haensch.