DC BEHAVIOUR OF PLANAR CARBON NANOTUBE FIELD-EFFECT TRANSISTORS

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The carbon nanotube field-effect transistor (CNFET) has attracted a great deal of interest due to predictions of its superior performance over that of ultimately-scaled silicon MOSFETs [1, 2]. While significant progress has been made in predicting its behaviour, simulations have primarily focused on azimuthally invariant structures, such as the cylindrically-gated CNFET [2, 3]. While this may be an ideal structure in terms of reducing short-channel effects, it poses serious difficulties in terms of its realization, and as a result, rigorous experimental verification of the theoretical models has proved difficult. Some preliminary work has been performed in simulating planar structures [4], however, it is not clear in that work if azimuthal variation in the electrostatics has been neglected in order to effectively reduce the nanotube simulation to one dimension.

In this work, we consider a device with a planar gate electrode coupled to an infinitely-long carbon nanotube (Fig.1). The channel of the CNFET is an intrinsic portion of the nanotube of some finite length, and the rest of the CN is assumed to be doped by some means, such as chemical doping [5]. The two semi-infinite, doped regions form the source and drain electrodes. In order to simulate this device, we solve Poisson's equation using finite elements in three dimensions, and compute the charge on the nanotube via the Green's function for a nearest-neighbour, tight-binding Hamiltonian. The semi-infinite source and drain are treated using self-energies [6], which are computed via a quadratic matrix equation [7]. Iterations are performed until self-consistency is achieved between the Poisson solution and the charge calculation.

By considering the individual atoms in the Green's function calculation, we are able to compute charge variations, and hence potential variations, around the nanotube circumference. This permits the simulation of a range of geometries that are more experimentally viable, and, hopefully, will provide a useful tool for device design and analysis. By treating more realistic structures, we provide a closer connection between theory and experiment: one that will allow for detailed verification of the adequacy of the nearest-neighbour tight-binding approximation in modeling CNFETs.

References:

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Figures:

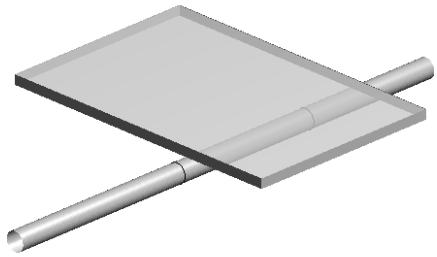

Figure 1 - The model geometry considered in this work: a single carbon nanotube below a planar gate electrode. The portion of the nanotube directly below the gate is the undoped channel, and the doped source and drain are connected to it.