Simulation of electronic states and transport properties of silicon nanowires with random dopant distribution

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Highly doped silicon nanowires have been demonstrated to show single-electron charging effects up to about 77K. Memory and logic circuits have already been fabricated [1,2]. However, these wires are uniform and have no intentional geometrically-defined islands. We are investigating the effects of the random distribution of dopants in these wires.

We report on numerical calculations of electron density distribution. In order for the problem to be solved in a reasonable amount of computer time, we approximate the wire to a 2DEG. Furthermore, to study only the effect of dopant distribution only, we neglect surface states, defects and any Fermi-level pinning, which are also mechanisms that might produce islands.

In the simulation, the electron distribution is first calculated under the Thomas-Fermi approximation. We show that, for a range of Fermi levels, the structure breaks up into a series of islands. We then calculate the capacitances among the naturally-formed islands and make a (gross) estimate of the tunnel resistance to form a circuit-level description that can be used as input to a single-electron simulator. The aim of this work is to study the range of threshold voltages produced in these systems and whether a lumped-element model of the system is an appropriate description.

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[2] N.J.Stone, H.Ahmed, Electronics Letters, 35 pp.1883-1884 (1999)