Is Self-Heating Important in Nanowire FETs?

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Modern technology has enabled the fabrication of materials with characteristic dimensions of a few nanometers. Examples are superlattices, nanowires and quantum dots. Thermal transport in these low-dimensional nanostructures is important for next-generation microelectronic cooling techniques, novel solid-state energy conversion devices, and micro-nanoscale sensors.

We have previously investigated 2D fully-depleted SOI device structures, where we observed that current degradation due to self heating effects is smaller in shorter channel length devices due to increased non-stationary transport, and reduced thermal resistance of the underlying buried oxide. To address self-heating effects in nanowire we use the electro-thermal simulator developed at ASU, which solves the Boltzmann transport equation in a self-consistent way for electrons and the energy balance equations for acoustic and optical phonons. The thermal conductivity values for the nanowire are taken from experimental measurements reported by Li Shi et al.

In this work we focus on investigation of self-heating effect in 10 nm wide, 7 nm thick and 10 nm long channel of a silicon nanowire transistor. The difference between this structure and the previously investigated 2D fully depleted SOI transistors is that the SiO2 is now all around the structure, not just at the top and the bottom. Because SiO2 has very low thermal conductivity, and the nanowire itself has low thermal conductivity (because of phonon boundary scattering in the rectangular cross section), self heating effects are more pronounced in the nanowire transistor when compared to the same channel length fully-depleted SOI device.

At the moment we are investigating current degradation due to self-heating effects for nanowires with arbitrary crystallographic directions. In these calculations the proper thermal conductivity tensor and its geometry and temperature dependence is being taken into account.