PHYSICS-BASED MODEL OF DISILICIDE/SILICON NANOWIRE HETEROSTRUCTURE TRANSISTORS

D. Jiménez[a], M. Dubois[b], and S. Roche[b]
[a]Departament d'Enginyeria Electrònica (Universitat Autònoma de Barcelona), Spain
[b]DSM/DRFMC/SPSMS (Commisariat à l'Energie Atomique), France
Contact: david.jimenez@uab.es; mathieu-j.dubois@cea.fr; stephan.roche@cea.fr

Silicon nanowire field-effect transistors (NW FETs) are being the subject of very intense research as building blocks for the bottom-up approach to nanoelectronics, owing to the potential control of physical and chemical characteristics during synthesis, providing a unique electronic structure and reduced carrier scattering caused by one-dimensional quantum confinement effects [1-4]. Very promising materials for defining source-drain contacts of the NW FETs are disilicides, such as $NiSi_2$, $CoSi_2$, and $FeSi_2$, due to the extremely low mismatch between their (111) surface and the silicon (111) one [5].

At present, an important issue is to dispose of a physics-based model of the current-voltage characteristics of FETs based on disilicide/silicon nanowire heterojunctions, in order to interpret experimental results at this early stage of development, guide the design and project NW FET performances. In this work we propose a simple model that accounts for the relevant physics phenomena, such as: (a) thermionic and tunnel emission over a Schottky barrier; (b) ambipolar conduction; (c) ballistic transport; (d) multimode propagation; and (e) electrostatics dominated by the nanowire capacitance. Fig. 1 illustrates the transfer characteristic of an hypothetical NW FET computed by the proposed model. The strong point of the model is an accurate treatment of the disilicide/silicon interface, accounting for quantum reflections in reciprocal space due to wavevector mismatches between incoming and outgoing states. The exact electronic structure of each disilicide is taken into account, allowing the calculation of the energy dependent current distribution at the interface (Fig. 2). In this way, we can include, in our model, the influence of the chosen material on the performance of the nanodevice.

References:

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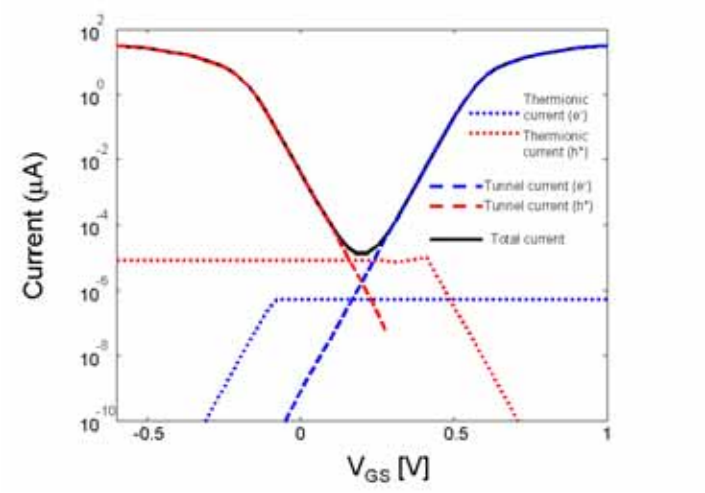

Figure 1. Transfer characteristic at room temperature of a coaxially-gated NW FET with a diameter of 1.42 nm, and silicon oxide thickness of 2 nm, showing ambipolar conduction (left branch: dominated by tunneling of holes through the Schottky barrier to the valence band; right branch: due to tunneling of electrons through the Schottky barrier to the conduction band). A Schottky barrier height of 0.65 eV, and V_{DS}=0.4 V were assumed.

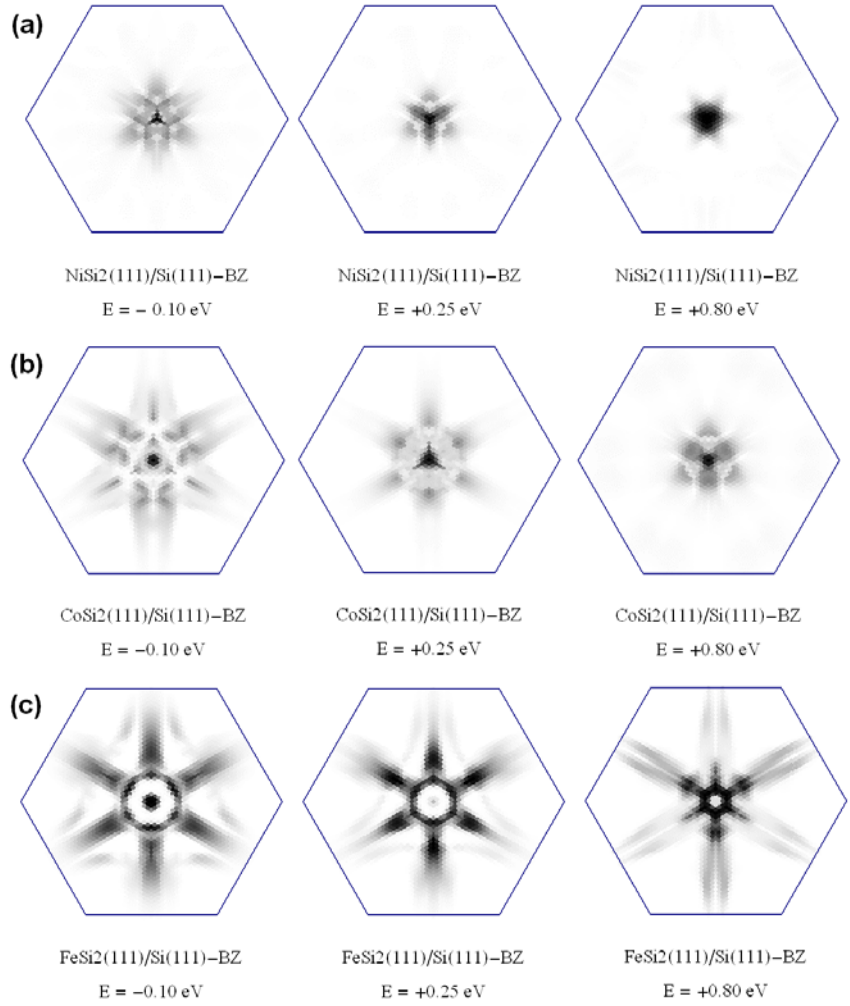

Figure 2. Energy dependence of the computed reciprocal-space current distribution, at the heterojunction interface, for $NiSi_2$ (a), $CoSi_2$ (b) and $FeSi_2$ (c). Energies are referred to the Fermi level of the disilicide set to 0 eV