THEORY & MODELLING of SINGLE IMPURITY SPECTROSCOPY in NANOWIRES and ULTIMATE MOS DEVICES

A 2 years postdoctoral position starting around June 2011 is opened at CEA/INAC (Grenoble, France) on the theory and modelling of the electronic and transport properties of single impurities in nanowire and MOS devices.

The effect of single dopants on the electrical properties of short-channel devices is a major preoccupation of the microelectronics community. The fluctuations of the number and position of the dopants diffused from the source and drain contacts for example is one of the largest source of variability in ultimate MOS transistors. In addition, the electronic and transport properties of each individual dopant is expected to be dependent on its surroundings (dielectric environment, neighbouring impurities, etc...). The low temperature $I(V)$ characteristics of such transistors actually display well defined Coulomb blockade diamonds below the threshold voltage (Fig. 1), which are the fingerprints of the tunnelling through one up to a few dopants in the channel [1]. These outstanding experiments provide, in particular, a direct measure of the energy level structure of the neutral and charged impurities. While the data clearly show that the electronic properties of dopants are very different in such complex environments, a comprehensive analysis is still missing. Meanwhile, further experiments are carried out at CEA/INAC to make innovative devices (such as latch switches) based on single-electron (Coulomb correlated) transport through systems of few impurities.

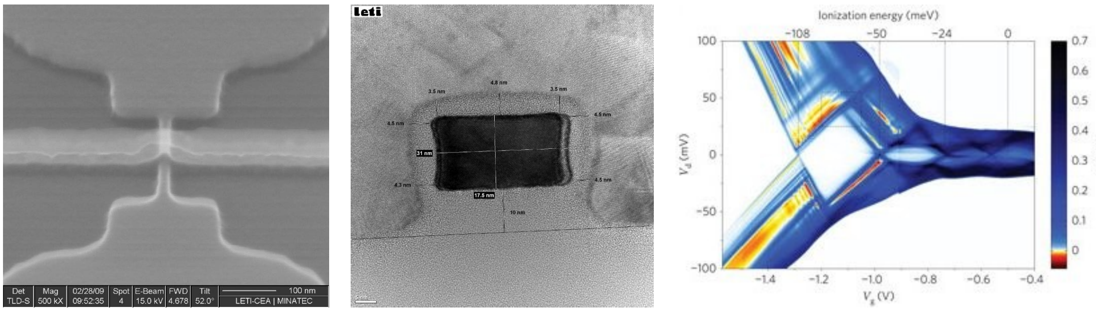

Figure 1: Silicon-on-insulator transistors used for single-impurity spectroscopy (left: top view; middle: cross section of the channel), and Coulomb diamonds measured at low temperatures just below the threshold voltage of such devices (right). The diamonds display complex features associated with the tunnelling of electrons trough one or a few impurities in the channel. Adapted from Ref. [1].

The laboratory of atomistic simulation (L_Sim) of CEA/INAC and the CNRS/IEMN have a recognized expertise in the modelling of the electronic and transport properties of dopant impurities [2-5] using atomistic tight-binding methods. The aims of this postdoctoral position, opened at L_Sim, are:

- To model the electronic structure of neutral and charged dopants in realistic device geometries (including contacts, gate oxides and metals, …), in order to understand the experimental data and the physics of impurities in complex dielectric environments. Accurate (possibly self-consistent) tight-binding models will be used for that purpose, supplemented with original approaches for the calculation of the dielectric response of the system. The possibility to use the electronic structure of the impurities as a probe of their position in the device will be investigated, in close connection with the experiments and with the variability issue in microelectronics.
- To model the transport through few impurity devices in the Coulomb blockade regime, in order to assess the feasibility of such devices, and to help their design and characterization.

This work takes place in the context of a national project, which will give the candidate the opportunity to interact with the experimental group of CEA/INAC [1], and to collaborate with other French theory labs, in particular CNRS/IEMN (Lille) and CNRS/IM2NP (Marseille).

The candidate should send her/his CV to Yann-Michel Niquet (yniquet@cea.fr), with a list of publications, and contact details of two persons for references.

The application is opened until March 1, 2011. **… ⇥**

References:

[1] *Single-donor ionization energies in a nanoscale CMOS channel,*
M. Pierre, R. Wacquez, X. Jehl, M. Sanquer, M. Vinet and O. Cueto,
Nature Nanotechnology **5**, 133 (2010).

[2] *Ionization energy of donor and acceptor impurities in semiconductor nanowires: Importance of dielectric confinement,*
M. Diarra, Y. M. Niquet, C. Delerue and G. Allan, Phys. Rev. B **75**, 045301 (2007).

[3] *Screening and polaronic effects induced by a metallic gate and a surrounding oxide on donor and acceptor impurities in silicon nanowires,*
M. Diarra, C. Delerue, Y. M. Niquet and G. Allan, J. Appl. Phys. **103**, 073703 (2008).

[4] *Ab initio calculation of the binding energy of impurities in semiconductors: Application to Si nanowires,*
Y. M. Niquet, L. Genovese, C. Delerue and T. Deutsch, Phys. Rev. B **81**, 161301(R) (2010).

[5] *Impurity scattering in gated silicon nanowires,*
M. P. Persson, H. Mera, Y. M. Niquet, C. Delerue and M. Diarra,
Phys. Rev. B **82**, 115318 (2010).

Additional informations about L_Sim:
http://inac.cea.fr/sp2m/L_Sim/
http://inac.cea.fr/sp2m/L_Sim/Qui/YMNiquet/

More about Grenoble and its surroundings:
http://www.isere-tourisme.com/main-contents/isere-in-one-click/regions-108-2.html