1D quantum-mechanical effects on the carrier concentration distribution, threshold voltage and gate-channel capacitance in the Double-Gate MOSFETs

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In order to achieve high performance circuits, CMOS is being pushed toward channel length down to 10nm. A lot of technological approaches have been proposed to overcome the scaling limits imposed by fundamental nature, such as inversion layer capacitance and low carrier mobility of a high impurity concentration channel. One of the most promising structure is the Double-Gate SOI MOSFETs, which uses the concept of volume inversion where the whole silicon film is in strong inversion. In this operation mode the Double-Gate transistor exhibits excellent device performances: high transconductance, near ideal subthreshold slope, minimized drain-induced barrier lowering or sharing, near ballistic drive current for the shortest lengths, low subthreshold intrinsic capacitance.

In addition to the coupling phenomena between the gates, well-known in fully depleted MOSFETs SOI technology, it is mandatory to take into account the confinement of inversion layer carriers in the potential well defined by front and back gate oxides and a silicon film of the order 10nm to 5nm. Consequently the inversion carriers must be treated in a quantum manner as a two-dimensional gas.

In this work, we investigate the dependence relation between carrier distribution and several technological parameters such as silicon film thickness, doping film, oxide thickness, oxide and gate materials.

We have developed a dedicated software to study this dependence on 1D cross section of DG MOSFETs. We consider two descriptions: the classical model based on the Poisson equation with Fermi-Dirac statistic, and the quantum model based on a self consistent resolution on the Schrödinger and Poisson equations. The quantum polydepletion in the gate is no considered.

The simulation structure is constituted by two symmetrical gates and p type silicon body uniformly doped. Both front and back gates are biased by the same voltage. Our study is focused on 1D effects on different electrical parameters as electron concentration distribution, threshold voltage or gate capacitance, and the results obtained, classical and on quantum models are compared.

Some of our first simulation results have reported on the following figures. Further results concerning these simulations will be shown in the extended paper.

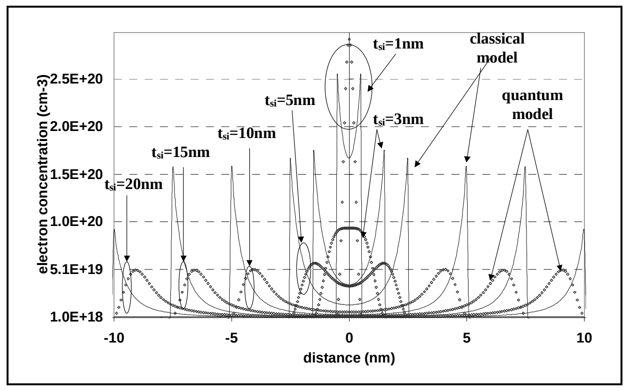

Fig. 1. Influence of the body film thickness on the electron concentration distribution according to the classical model and quantum model (without wave function penetration in the oxide). Tox=30A, Na=10^{15}cm^{-3} and Vg=2V.

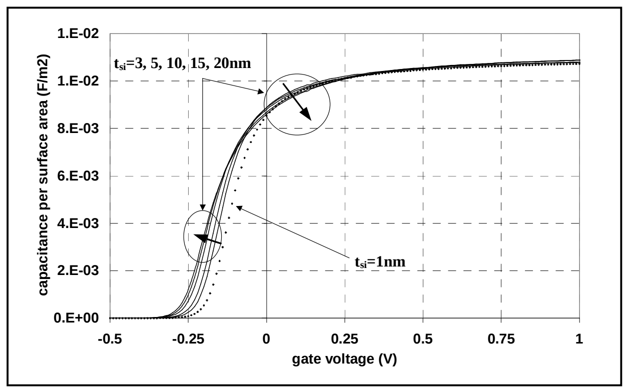

Fig. 2. Influence of the body film thickness on the capacitance per surface area according to the classical model. Tox=30A, Na=10^{15}cm^{-3}.

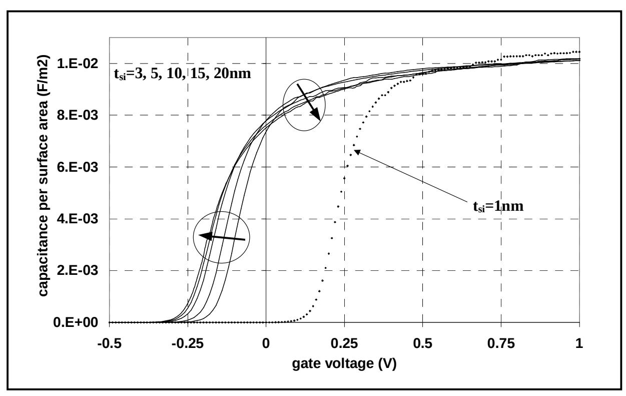

Fig. 3. Influence of the body film thickness on the capacitance per surface area according to the quantum model. Tox=30A, Na=10^{15}cm^{-3}.