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A Physically Based Quantum Correction Model for DG MOSFETs

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Due to the strong impact of quantum mechanical effects on the characteristics of todays semiconductor devices, classical device simulation without quantum correction is not sufficient to provide proper results. Besides tunneling, the effect of quantum confinement strongly affects the characteristics of bulk, silicon-on-insulator (SOI), and double gate (DG) MOSFETs under inversion conditions. Due to quantum confinement, which affects the local density of states, the carrier concentration near the gate oxide decreases while classical simulation predicts an exponential growth near the gate oxide.

Schrödinger Poisson (SP) solvers, which deliver a self consistent solution of a quantum mechanically calculated carrier concentration and the Poisson equation, provide accurate results. However, since the evaluation of the quantum mechanical electron density is based on the calculation of the eigenstates of a Hamiltonian, which is computationally very demanding, the application of SP solvers is impractical. In order to obtain proper simulation results at greatly reduced CPU time, several quantum correction models for classical simulation have been proposed. They extend the range of validity of classical transport models to highly scaled devices in the deca nanometer regime. The most advanced model, the Improved Modified Local Density Approximation (IMLDA) model (C. Nguyen et al., Proc. NSTI-Nanotech, 2005, vol. 3, pp. 33-36), relies on the solution of the Schroedinger equation for a single step-like potential profile and is calibrated for bulk MOS structures. For these structures, this approach delivers good agreement for CV-characteristics. However, this model is not intentioned to be used for DG MOSFET structures, which demand a different approach. To our best knowledge, the usability of several present available quantum correction models for highly scaled DG MOSFET devices is very limited. In this work, we present a specific approach for state-of-the-art DG MOSFET devices. The strong quantization in perpendicular direction results in a two-dimensional electron gas which can be well approximated with an infinite square well potential. The eigenstates are estimated with the according analytical approach. This assumption allows to determine a quantum correction potential which modifies the band edge energy in a way to reproduce the quantum mechanical carrier concentration. We implemented this model in our general purpose device simulator MinimosNT. The carrier concentration calculated from the new model shows very good agreement with the self consistent Schrödinger Poisson solution. Since the derived CV-characteristics are based on the accurate carrier concentration, no further fitting is necessary.

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