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Quantum-Mechanical Simulation of Multiple-Gate MOSFETs

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Abstract

A self-consistent solution of the 2D Schrödinger-Poisson equations is used to analyze Multiple-gate MOSFETs. Classical simulations overestimate the peak density compared to quantum simulations and therefore the importance of the corner effects. The impact of the corner rounding on the electron distribution has also been analyzed.

Introduction

In order to shrink channel lengths into the nanometric range it is necessary to prevent the short channel effects since they degrade the device performance. The use of several gates has demonstrated a good electrostatic control of the channel and therefore the possibility of a higher reduction of the channel length compared to traditional bulk MOSFETs. Structures such as FinFETs, Trigates, Gate All Around (GAA), Pi and Omega-gate MOSFETs are included into the category of Multiple-gate MOSFETs.

Device Simulation

To get a fast convergence, the 2D Schrödinger and Poisson equations have been self-consistently solved using the predictor-corrector scheme proposed by Trellakis et al [1]. This algorithm has been proved as reliable and robust as far as enough number of eigenvalues and eigenfunctions are included in the calculations. In all the simulated devices we have considered an undoped substrate and a metal gate workfunction of ϕ_m=4.63eV. Fig. 1 shows the classical electron distribution (CED) corresponding to a Trigate MOSFET with silicon height (H_{Si}) and width (W_{Si}) of 10nm, gate oxide thickness (T_{ox}) of 2nm and gate voltage (V_G) 1V. Fig. 2 shows the QED for the same structure. Important differences are observed between both figures. The CED is concentrated at the Si-SiO_2 interface with a maximum at the corner of $n_{max}=2\times10^{20}cm^{-3}$. This value is eight times the maximum obtained including quantum effects: $n_{max}=2.5\times10^{19}cm^{-3}$. To get these results, the simulator computes a sufficiently high number of energy levels and wave functions. These results could also be applied to evaluate the transport properties of the device. The simulator offers the possibility of specifying the curvature of the silicon substrate corners, and of the surrounding oxide, independently. This fact allows us to study the behaviour of a great amount of geometries, and evaluate the influence of the corner effects. These effects are produced by the coupling between different gates which originates an favourable area for the flow of carriers [2]. This simulator is able to deal with rounded geometries since it employs finite elements. In a first step, a low-resolution mesh is used to compute a preliminary solution. We use this solution to identify the device regions where the mesh has to be refined, and where the mesh could be less dense. This allows us to greatly reduce computational costs. Fig. 3 shows the QED obtained in a Trigate MOSFET with square cross section and $H_{Si}=W_{Si}$=20nm, T_{ox}=2nm and V_G=1V. The electron density's maximum is close to the corners. Fig. 4 shows the QED in the same Trigate MOSFET where the upper corners of the silicon slab have been rounded with a curvature radius of 10nm. Now, the electron distribution is more uniform along the Si-SiO_2 interface. Fig. 5 shows the electric field in both devices. For the square cross section a peak is observed in the corners originating a maximum in the electron density.

Conclusions

A 2D Schrödinger-Poisson solver applicable to a wide variety of Multiple-gate MOSFET geometries has been developed. Classical simulations clearly

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overestimate the peak electron density and the corner effects. We have also shown that corner effects are greatly diminished by the rounding of the substrate corners.

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REFERENCES

[1] A. Trellakis, A.T. Galick, A. Pacelli, U. Ravaioli, *Iteration scheme for the solution of the two-dimensional Schrödinger-Poisson equations in quantum structures,* Journal of Applied Physics, **81**(12), 7880-7884, 1997.

[2] R. Ritzenthaler, O. Faynot, C. Jahan, S. Cristoloveanu, *Corner and Coupling Effects in Multiple-Gate FETs,* Proceedings of the Electrochemical Society, 283-288, 2005.

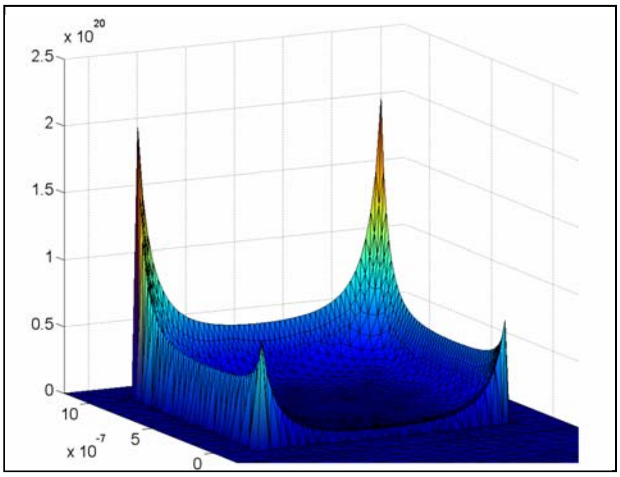

Fig. 1. CED in a Trigate MOS structure with H_{Si}=W_{Si}=10nm, T_{ox}=2nm and V_G=1V.

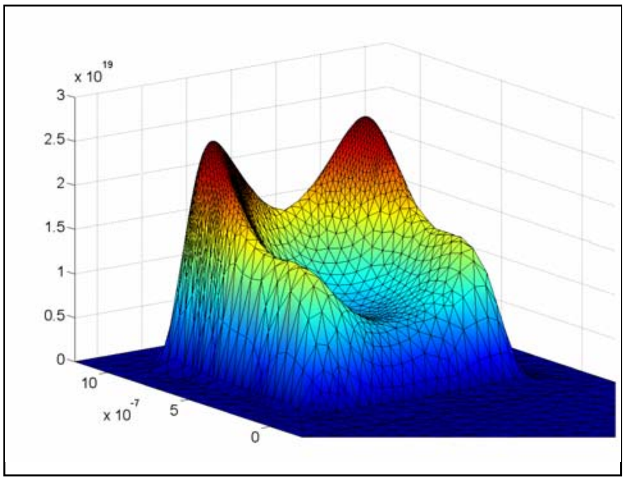

Fig. 2. QED in a Trigate MOS structure with H_{Si}=W_{Si}=10nm, T_{ox}=2nm and V_G=1V.

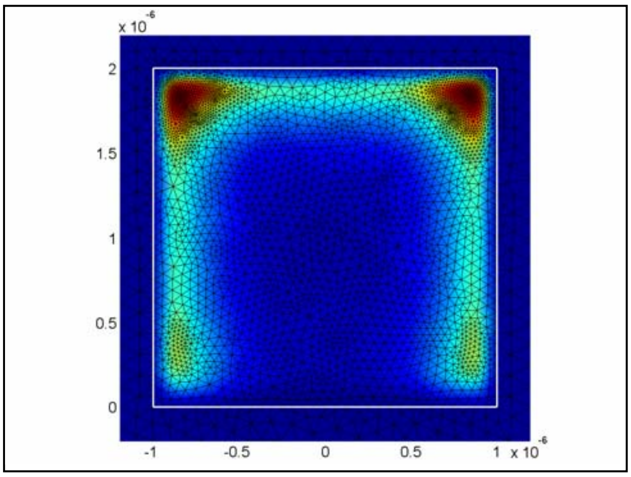

Fig. 3. QED in a Trigate MOSFET with H_{Si}=W_{Si}=20nm, T_{ox}=2nm and V_G=1V. Note the different resolution of the mesh in different regions of the structure.

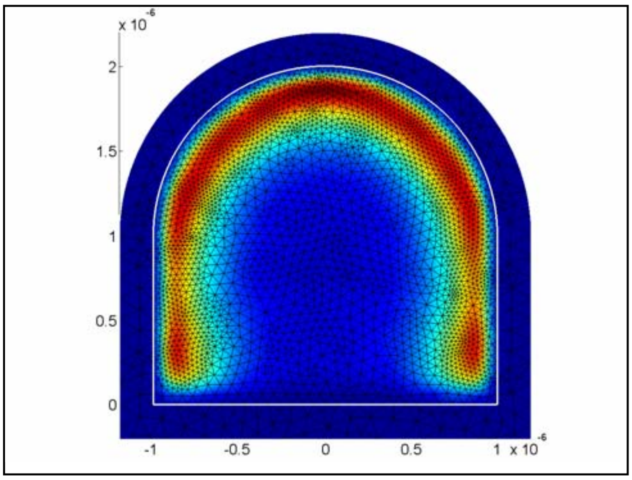

Fig. 4. QED in a Trigate MOSFET with H_{Si}=W_{Si}=20nm, T_{ox}=2nm and V_G=1V.

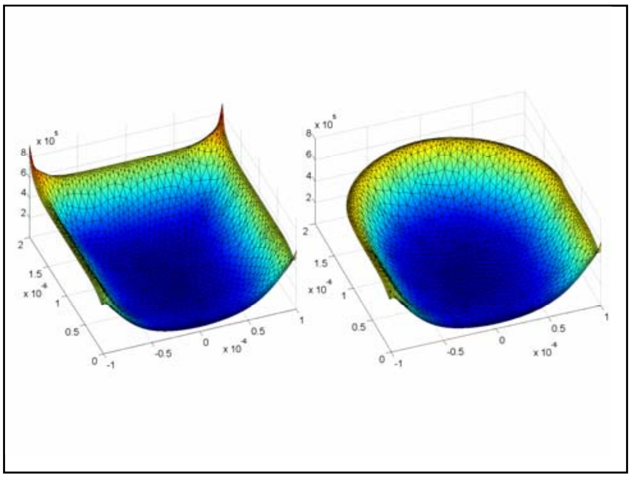

Fig. 5. Electric field in a Trigate MOSFET with square and rounded cross sections.