Advanced Models for Deep-Submicron Devices

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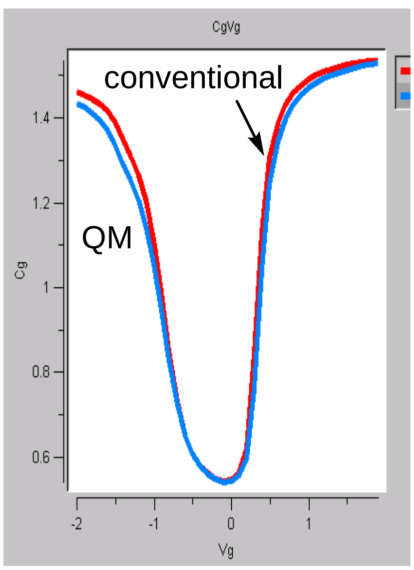
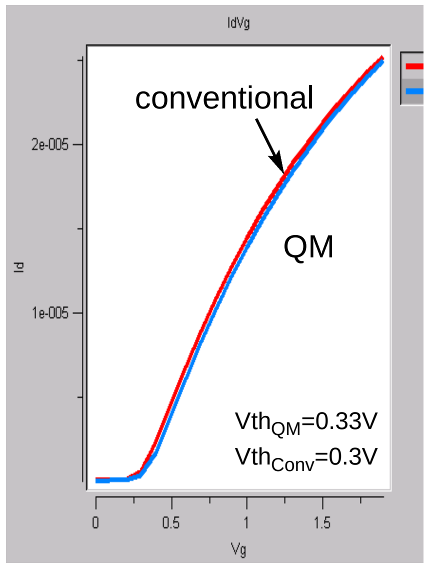
Electric behavior of deep-submicron devices with ultra-thin oxides and high channel doping concentrations is influenced by quantum mechanical quantization effects in the channel. These effects are observed as a bias-dependent widening of the electrically effective gate oxide thckness in comparison to the optically measured one.

This Quantum Mechanical (QM) correction is incorporated in SEQUOIA Device Designer using a model suggested by M. v. Dort [1]. The model introduces an effective band-gap widening near the Si-SiO_2 interface. The figure below shows the calculated gate capacitance versus gate bias CV curves

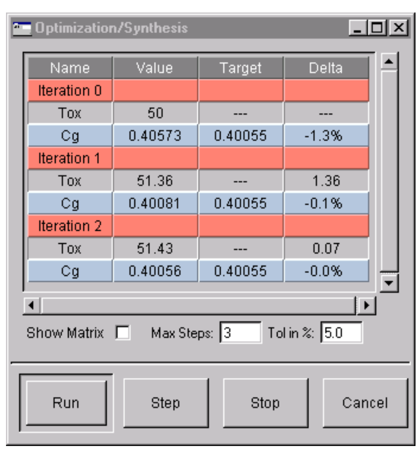


with (red curve) and without this model (blue curve). The test device is a 0.5 µm N-MOSFET with a gate oxide thickness of 50 Angstrom and a channel doping concentration of 2e17 cm^{-3}. Differences are clearly seen both in the inversion and accumulation parts of the CV curve. A threshold voltage shift of about 30mV is observed between the two calculations.

It is possible to obtain similar results using the conventional model as with the QM model if a modified oxide thickness is used. An electrically equivalent gate oxide thickness of 51.4 Angst-rom



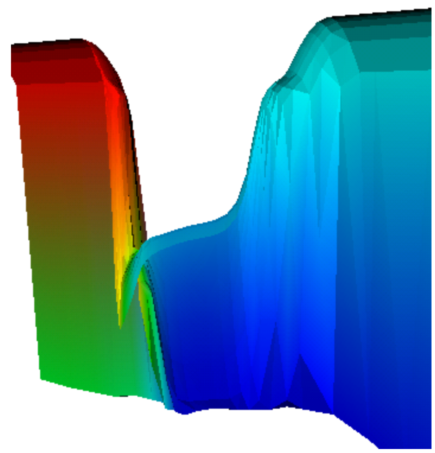
is calculated as a result of an inverse modeling problem. First a gate capacitance value is calculated using the QM model. In our example this value is 0.4 fF/µm. An optimization loop then calculates a gate



Name	Value	Target	Delta
Iteration 0			
Tox	50	---	---
Cg	0.40573	0.40055	-1.3%
Iteration 1			
Tox	51.36	---	1.36
Cg	0.40081	0.40055	-0.1%
Iteration 2			
Tox	51.43	---	0.07
Cg	0.40056	0.40055	-0.0%

oxide thickness which produces the same capacitance value in the absence of the QM model. The effective oxide thickness thus obtained depends on the bias conditions and is therefore not a substitute to the use of the complete QM model.

Effective band-gap widening induced by the QM model results in a decreased inversion layer carrier concentration as shown below.



Electron concentration in Off state shown as elevation. Surface color corresponds to electric potential.

SEQUOIA Device Designer accurately predicts the electric behavior of deep-submicron devices by incorporating quantum mechanical quantization and other relevant effects.

[1] M.J. van Dort, P.H. Woerlee, A.J. Walker, "A simple model for quantisation effects in heavily-doped silicon MOSFETs at inversion conditions," Solid-State Electronics, 3, 411 (1994)

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