Controlling Mesh Effects in Integrated Process and Device Simulation

*V. Axelrad, *M. Duane*
PDF Solutions, San Jose CA
**Advanced Micro Devices, Austin, TX*

Introduction

Mesh discretization effects can have a significant impact on obtaining meaningful results in statistical TCAD simulations. Discretization errors, i.e. inaccuracy of the solution due to too large or poorly shaped mesh elements, can be damaging in an absolute sense, as an offset of nominal values. Potentially even more dangerous are relative errors between statistical runs due to meshing noise, which can mask the desired sensitivity values, correlations, etc. This work discusses the application of an advancing-front mesh generation algorithm [1],[2],[3],[4] to study the sensitivity of MOSFET simulation results to a) mesh density and b) variation of physical process parameters (gate oxide thickness). It is shown that the utilized mesh generation algorithm can produce accurate results at a low cost. In contrast to the conventional approach, results obtained using the new mesh are more accurate and vary smoothly in response to variation of physical input parameters while requiring only about one third of the CPU time for a device simulation.

How Much Mesh is Enough to Simulate a MOSFET?

A 0.25 µm MOSFET was used to study the dependence of various electrical device parameters on mesh density. For these experiments, the device structure was generated using a commercially available 2D process simulator. The process simulation mesh density is controlled via initial mesh placement in the channel (Figure 1). In addition, a number of optimized device simulation grids were generated with pdMesh [1] which allows exact placement of quasi-orthogonal lines of elements in the channel, at pn-junctions, etc. (Figure 2). A vertical mesh spacing of 2A was used in pdMesh.

Device simulation was performed using both mesh types for various mesh densities, and electric parameters such as Vth, IdSat, IdLin, etc. were extracted using a commercially available device simulator. Results are summarized in Figure 3 for the linear region drain current Idlin (other parameters behave similarly). It is evident that while pdMesh-generated grids allow to obtain an accurate solution independent of the process simulator mesh (horizontal lines), using the conventional process simulator mesh shows strong dependence of results on the mesh spacing (upper lines). The reason is that pdMesh aligns its triangles to the actual material interface, while the process simulator mesh is simply a set of horizontal mesh lines placed without knowledge of the location of the material interface. Since the vertical location of the interface is not known a priori, static horizontal mesh lines do not allow precise control over the mesh spacing at the interface. For a given oxide thickness calculated Idlin values become similar at a vertical mesh spacing of about 2A.

As a result, better than 1% accuracy in Vth, Idlin, etc. is achieved using pdMesh with a channel mesh spacing of about 2A. This result is independent of the mesh density used in the process simulator at least in the range 2A to 10A. It is difficult to assure that same level of accuracy with a conventional process simulator mesh due to a strong dependence of the discretization on mesh spacing (Figure 3, upper lines).

Varying Gate Oxide Thickness

After establishing the necessary mesh resolution to obtain sufficient absolute accuracy, we can

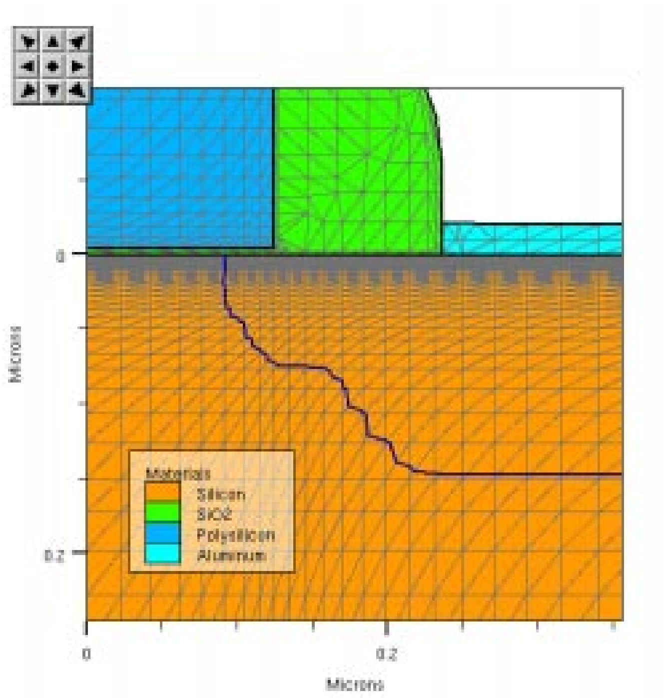

Figure 1 Process simulator mesh near the gate corner.

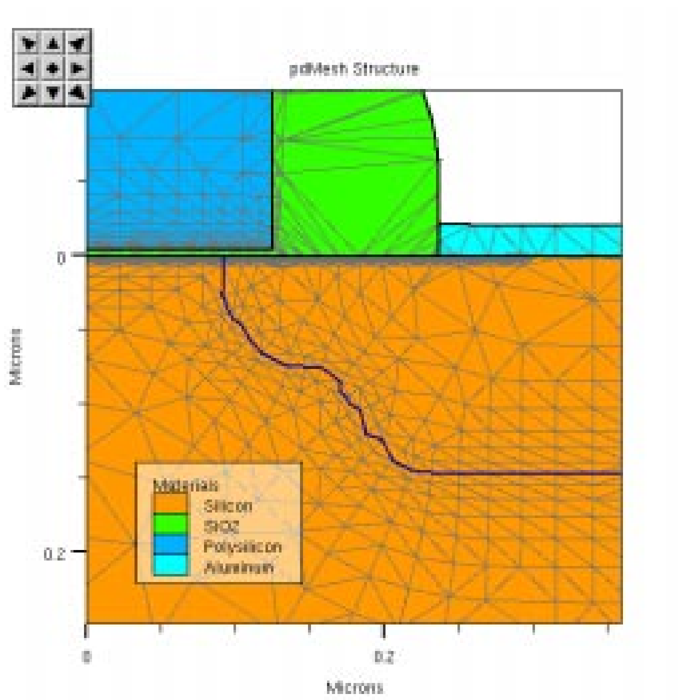

Figure 2 pdMesh generated MOSFET mesh

approach the study of how the results behave under varying process conditions. The gate oxidation time was varied to produce gate oxide thicknesses from 35 to 60 Angstrom. For each structure, a device simulation was carried out using a) the process simulation mesh and b) pdMesh-generated mesh following the oxide interface. Results are summarized in Figure 4. It is evident that while the quasi-orthogonal boundary mesh (bottom line) shows the true physical dependence of Idlin on oxide thickness, it is not possible to get the same results using the process simulation mesh even at a vertical mesh resolution of 5A (upper lines). At 2A channel mesh spacing the error finally drops below 1%, however there is still some residual oscillation of the solution. This is especially relevant for statistical simulations since the sensitivity of Idlin to Tox, their correlation, etc. clearly requires a smooth dependence of Vth on Tox unattainable with the conventional mesh unless extremely fine mesh density is used.

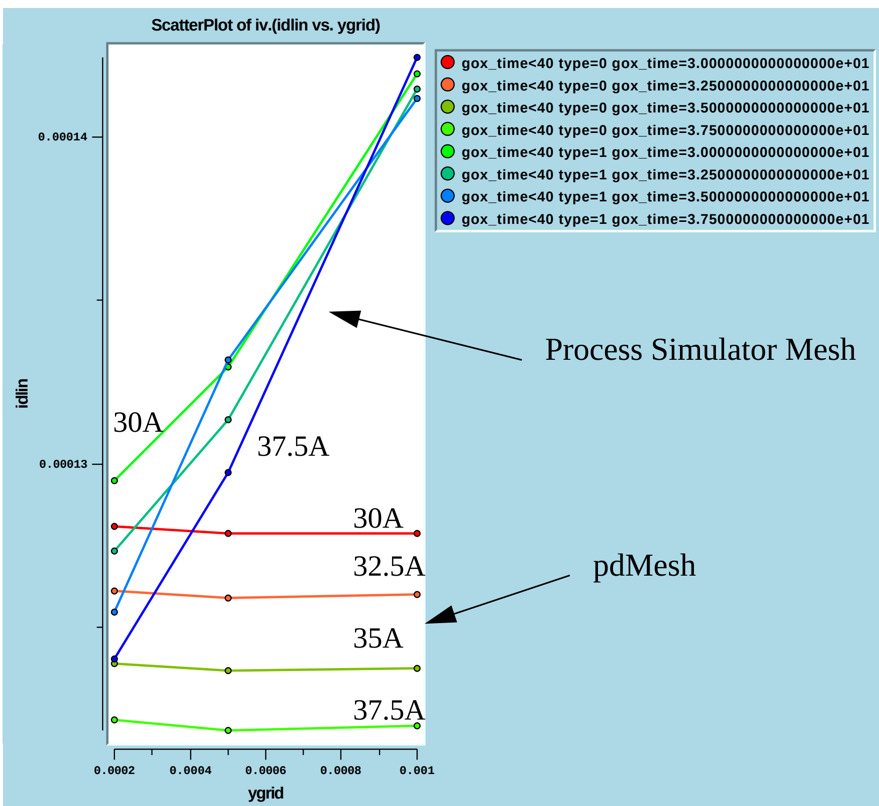

Figure 3 Calculated Idlin as a function of vertical channel mesh spacing of the process simulator mesh for several gate oxide thicknesses: lower lines — pdMesh, upper lines — process simulator mesh.

Oscillations of the Idlin versus Tox curves calculated using the process simulator mesh clearly show the effect of the oxide interface traversing successive mesh lines. Each time this happens, a spike is observed in the curve.

Conclusions

A study of solution accuracy as a function of mesh resolution and mesh type has been presented. It has been shown that an advancing wave-front mesh generation algorithm [1] is essential to assure solution accuracy especially across process control variations

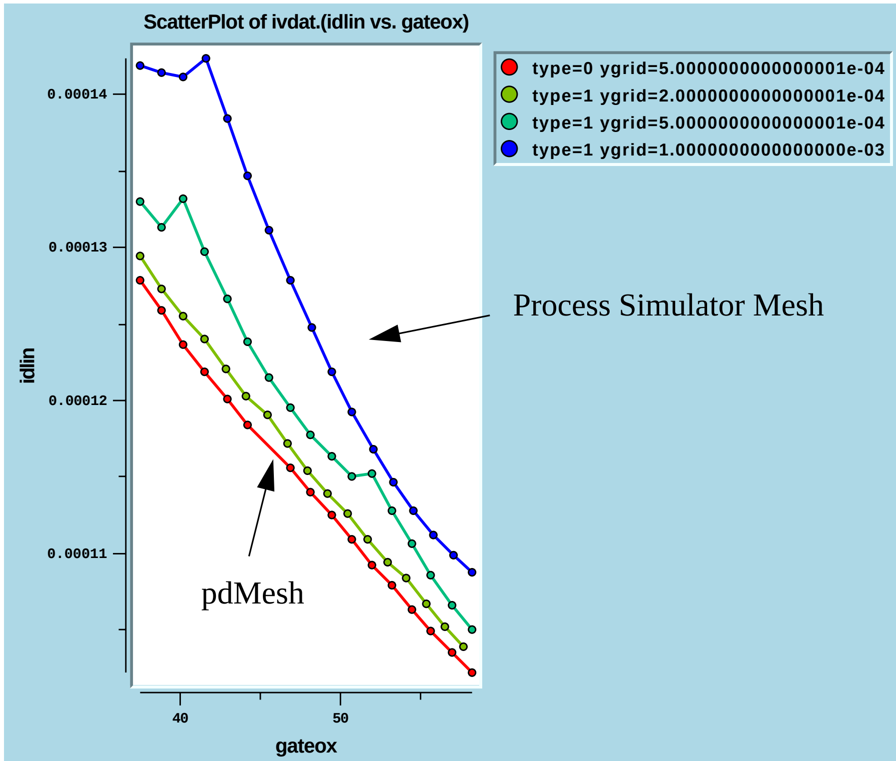

Figure 4 Calculated Idlin as a function of gate oxide thickness: lowest line — pdMesh, other lines — process simulator meshes with 2A, 5A and 10A vertical mesh spacing in the channel.

References

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