Hints, Tips and Solutions

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Q: Which implant and diffusion models should be used for simulating MOS channel profiles in *ATHENA*?

Previous articles in the Simulation Standard have highlighted the diffusion models required for accurate simulation of shallow source/drain junction formation[1] and Reverse Short Channel Effect (RSCE)[2][3]. However for complete simulation of MOS short channel behavior it is necessary to consider the diffusion of the channel implants before the source/drain processing.

The NMOS channel process typically consists of a low energy boron or BF_2 implant to adjust the threshold voltage. This is often combined with a deeper implant for punch through protection. These implants are followed by the diffusion cycle used to form the gate oxide. Consideration of oxidation enhanced diffusion and dopant loss into the growing gate oxide is important.

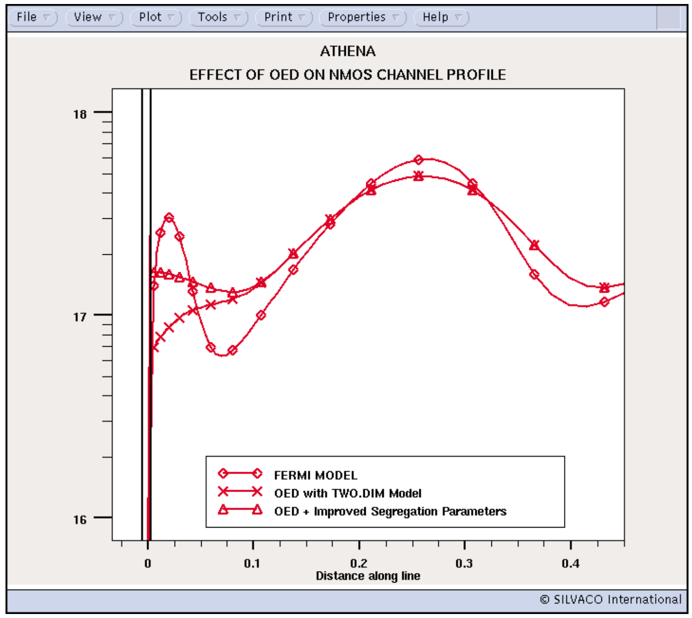

Figure 1. Comparison of FERMI and TWO.DIM models for NMOS channel implants and 8nm gate oxidation.

Firstly the as-implanted profiles should be simulated as accurately as possible. The default analytical SVDP implant models are accurate for boron implants of 5-80keV through native oxide or from 15-80keV through a thin screen oxide. For lower or higher energies it is recommended to use the BCA implant model. The results of the BCA simulation can be compared to the results from SVDP models. In some cases the results are similar and the quicker SVDP model can be used.

For subsequent diffusion steps with oxidizing ambients the `TWO.DIM` model must be selected on the `METHOD` statement. The `FERMI` model is not appropriate for these process steps. The `TWO.DIM` model correctly accounts for the injection of point defects into the substrate during oxidation and their effect on the diffusion rate of boron. Figure 1 illustrates the extra diffusion from the `TWO.DIM` model. Only 8nm of oxide was grown in this example. It is important to realize that the OED effect is not confined to the surface. The point defects diffuse quickly in silicon and affect the punch through implant profile too.

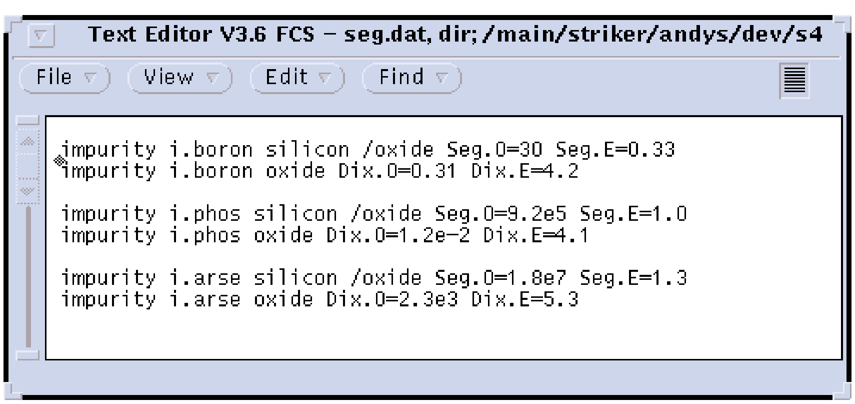

Figure 2. Temperature dependent segregation coefficients and oxide diffusion parameters for ***ATHENA***.

In addition to diffusion the channel implant has a dose loss by segregation into the gate oxide. This model is always enabled by default. Tuning the model is important though and Figure 1 shows that the effect of the segregation coefficient values can be down to a depth of 0.1µm.

Modeling segregation accurately requires a fine grid both at the silicon surface and in the oxide. The GRID.OX parameter can be used to set the grid spacing in thermally grown oxides. The fine oxide grid is required since the diffusion of the dopant in oxide away from the interface can be important. Figure 2 shows a set of parameters for both segregation coefficients and diffusion in oxides from [4]. The dataset in this work was evaluated on oxides down to 3.5nm thick. Experience has shown that this parameter set has provided a more realistic starting point for tuning.

The channel profile obtained using these models will be valid for large channel devices and gate CV test structures. At short channel lengths the effect of defects from the source / drain areas will alter the doping profile causing RSCE. To verify this long channel profile users can use EXTRACT to determine the threshold voltage and the CV curve from a 1D simulation or a slice from a 2D simulation before the source drain diffusion. When tuning MOS channel profiles using threshold voltage it is important to extract the threshold voltage vs. back bias data and to fit the slope of this data. Fitting the slope is more important than actual threshold value since this is affected linearly by gate work function and oxide charge.

References

[1] Hints, Tips and Solutions, Simulation Standard, February 1995

[2] Hints, Tips and Solutions, Simulation Standard, December 1995

[3] “Calibrating RSCE”, Simulation Standard, May 1998

[4] “Diffusion of As, P and B from Doped Polysilicon through Thin SiO2 Films into Si substrates”, Matsuura et al., J. Electrochem. Soc. November 1991.