Process Aware Hybrid SPICE Models Based on TCAD and Silicon Data.

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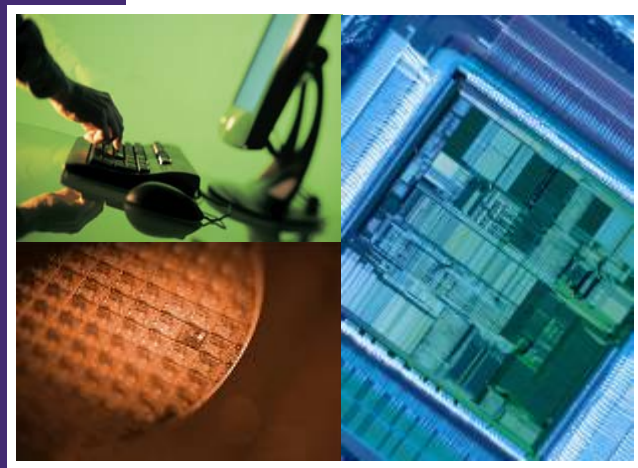

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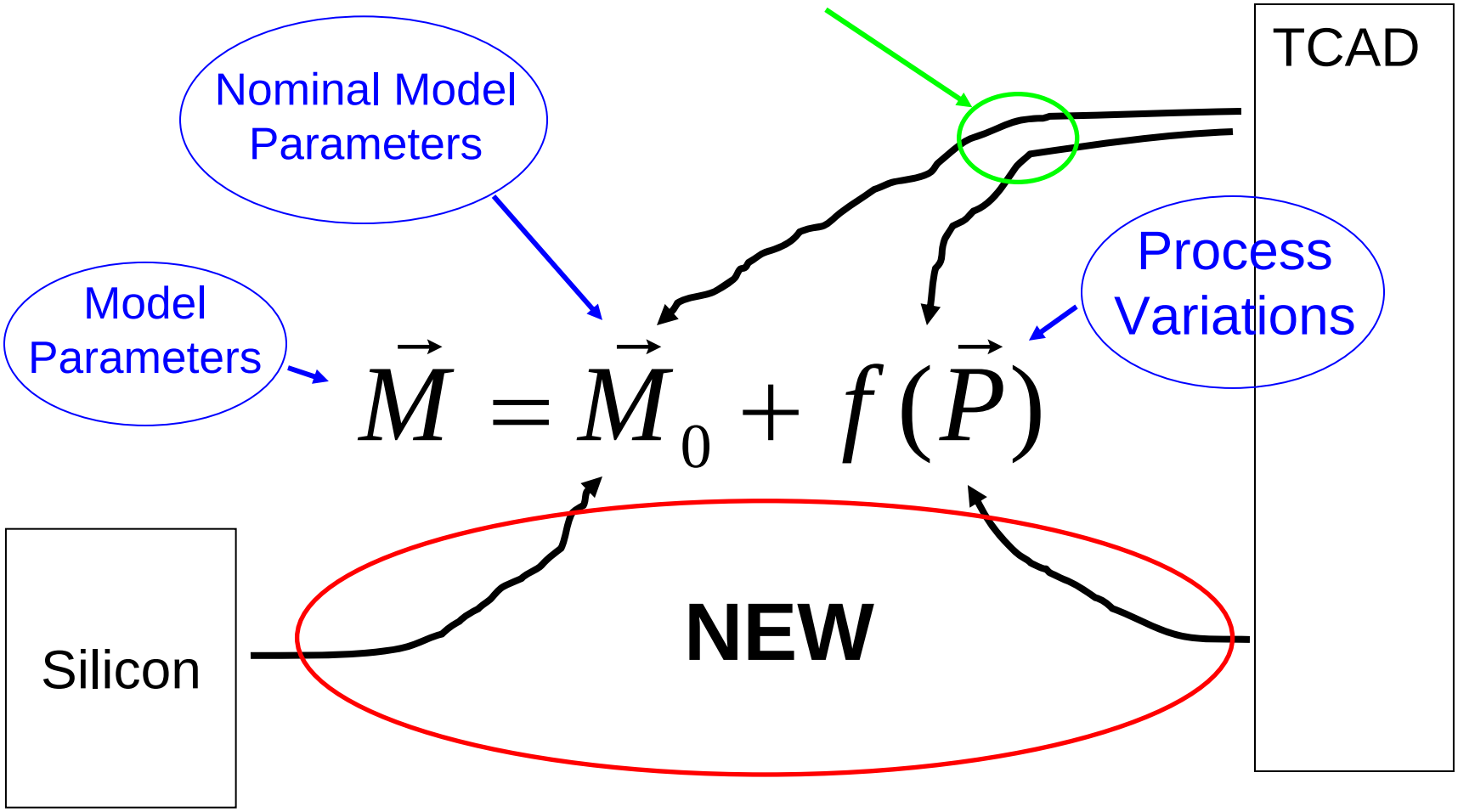
Motivation

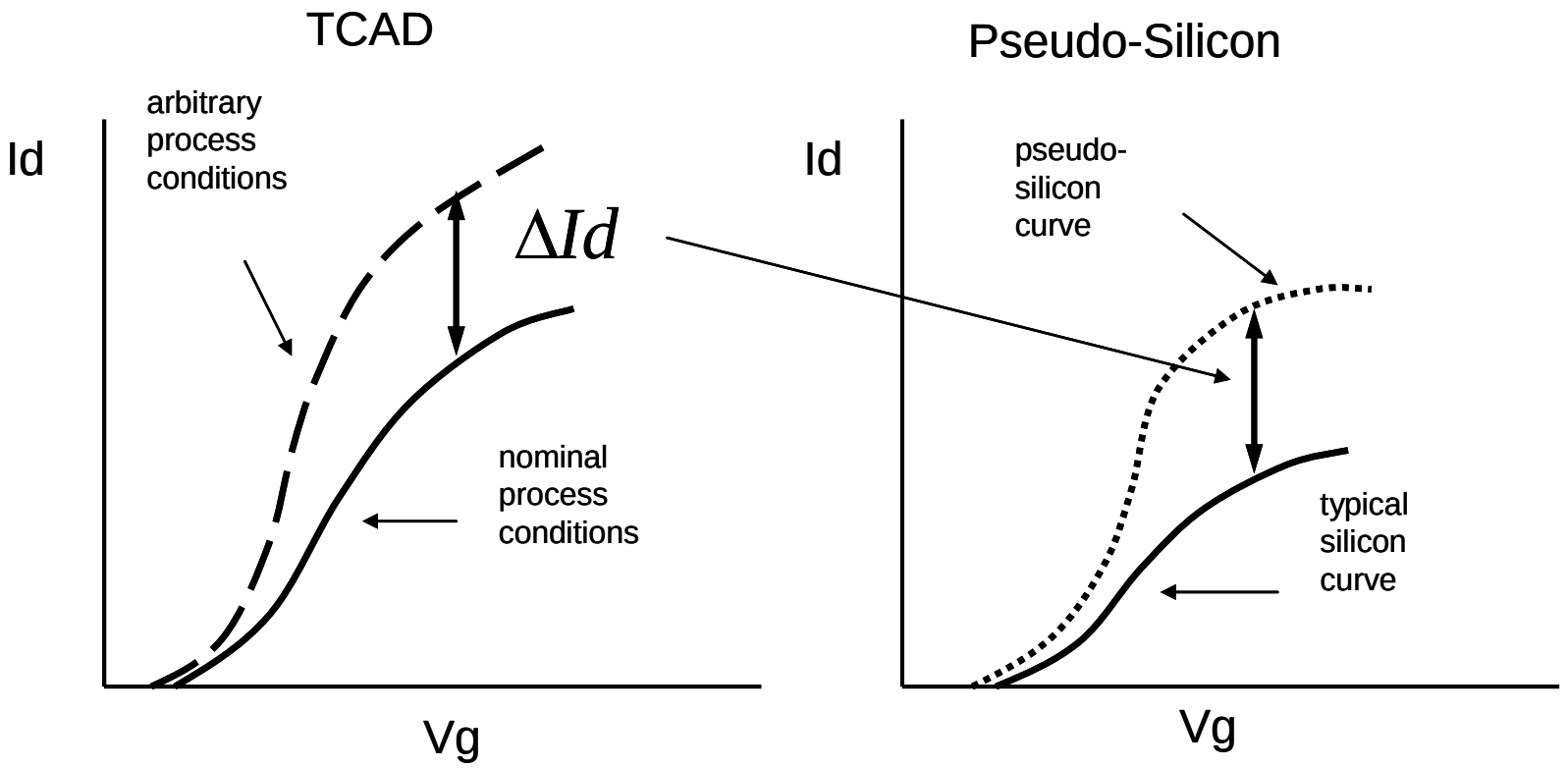
- Currently process variations are handled implicitly in SPICE (corner models)
  - No link between particular process conditions and transistor model
- We want to have an explicit link between process conditions and transistor's SPICE model

Prior Work[1]



[1]Nanotech2006,TCAD-based Process Dependant HSPICE Model Parameter Extraction

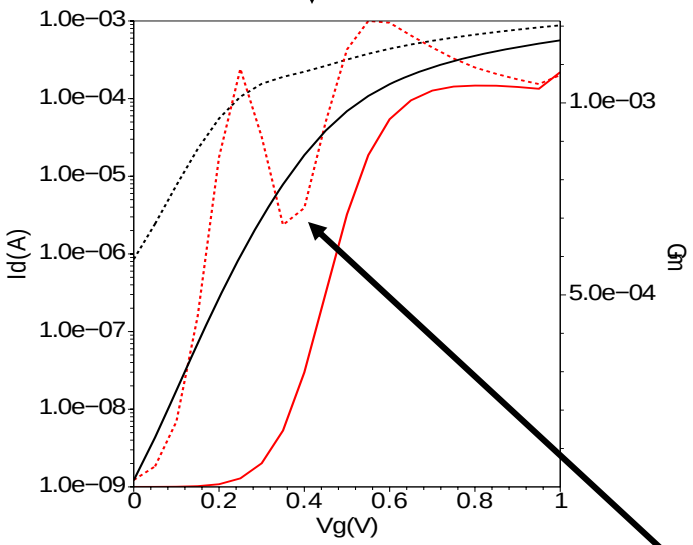
Pseudo-silicon Data Generation

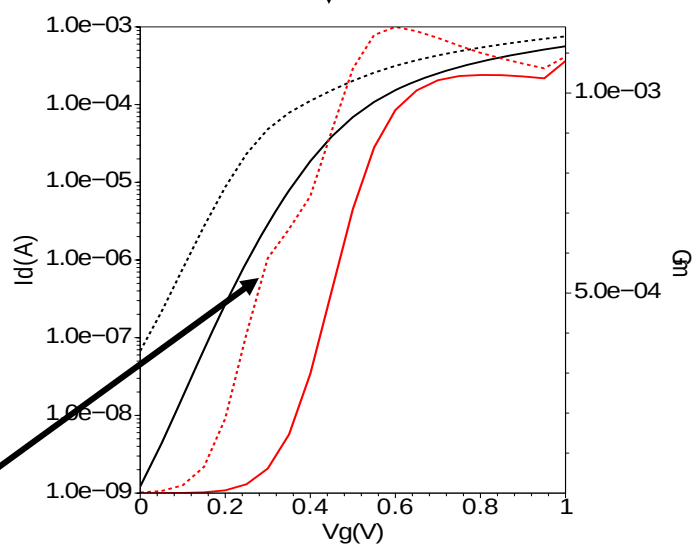


Data Shifting

$$Id_{pseudo} = Id_{silicon} + \Delta Id$$

$$Id_{pseudo} = Id_{silicon} \times \left(1 + \frac{\Delta Id}{Id_{tcad}}\right)$$





not acceptable

Gm Problem

acceptable

Unresolved Data Shifting Problems

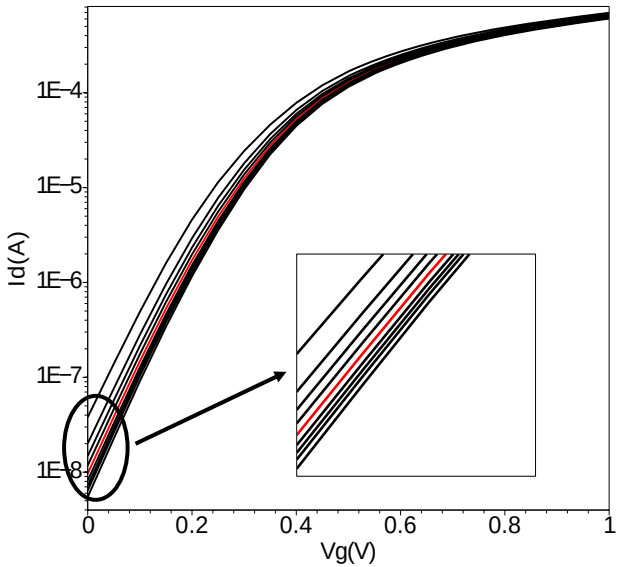
- Smoothness of 1st derivatives (Gm, Gds, Gmb) ?
- Smoothness of 2st derivatives ?
- Further research needed

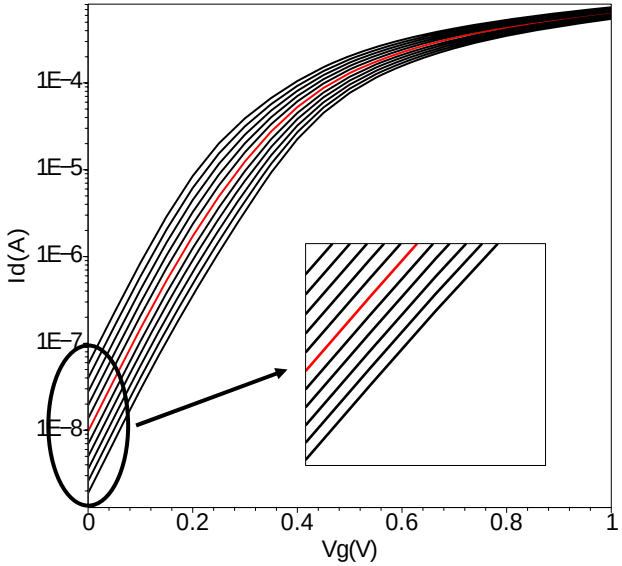
?

?

Pseudo-Silicon Data

Red Line – Silicon Curve
Black Lines – Pseudo-Silicon Curves

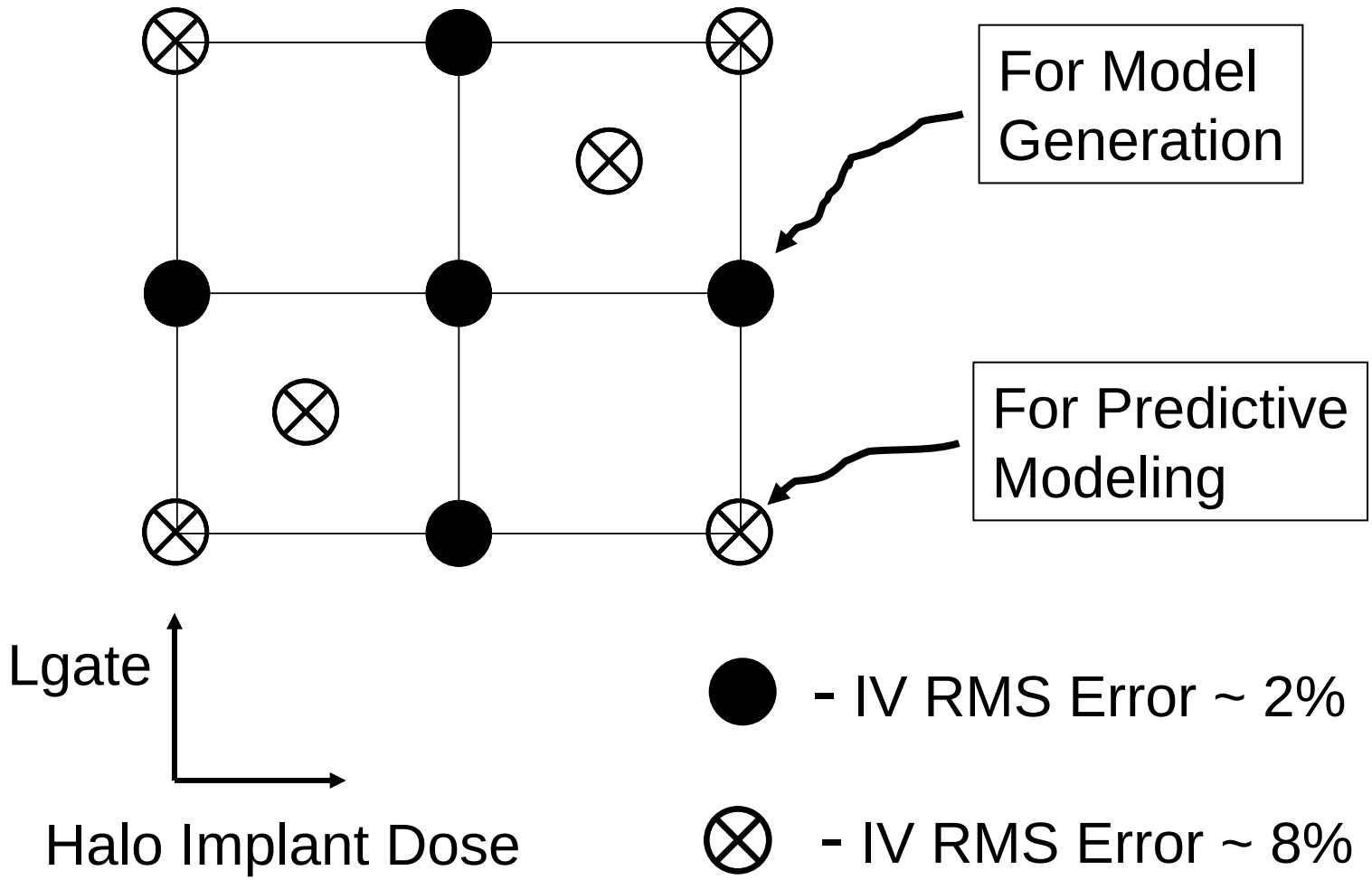




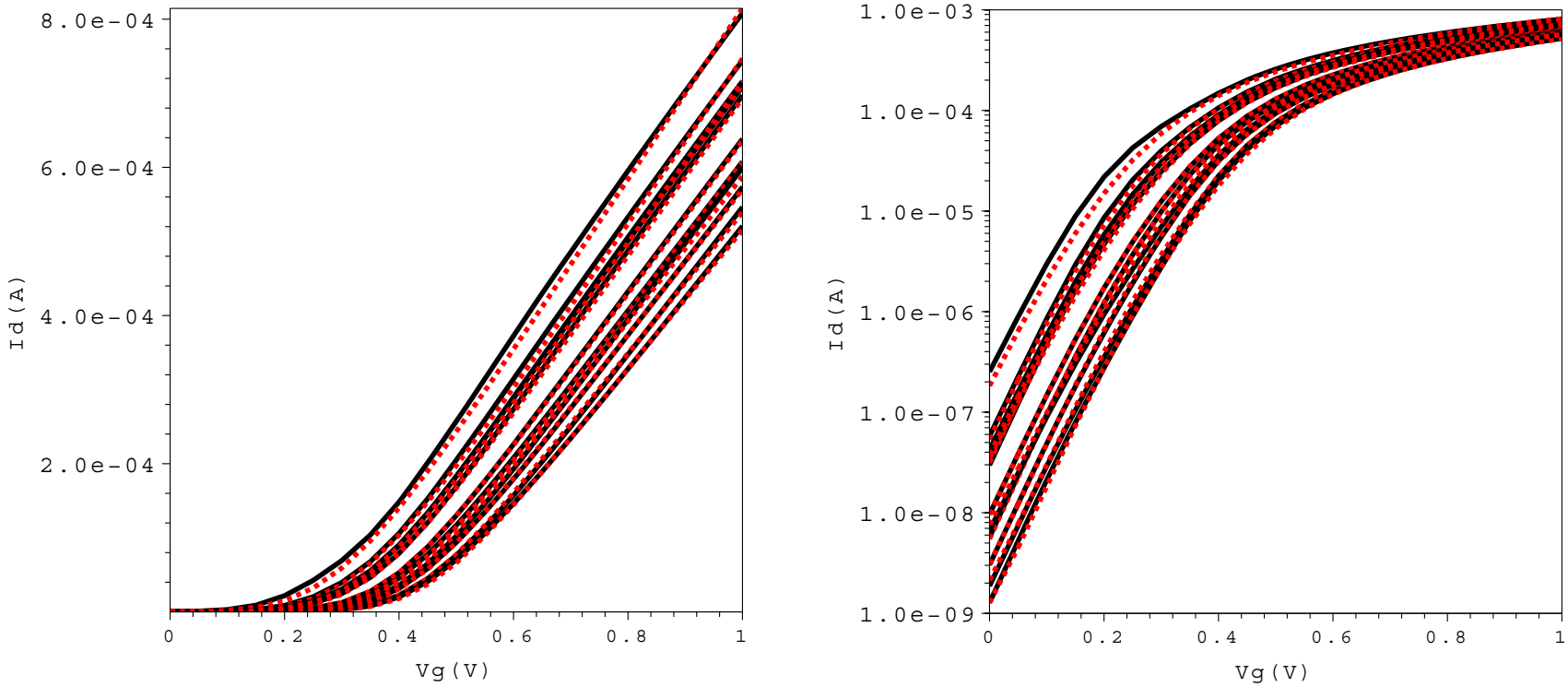
Lgate Variation ±10 nm

Halo Implant Dose Variation ±2.0e12

Hybrid Model Validation, DOE



Model Prediction, DOE



Black Lines – Pseudo-Silicon IdVg Curves
Red Lines – Hybrid BSIM4 Model Curves

All results are generated using single model card!

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Conclusions

- Hybrid SPICE Model:
  - Reproduces exactly Si data for nominal process
  - Takes advantage of smooth TCAD trends to provide good description of the process variations