Hints, Tips and Solutions

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Q: How is temperature dependent breakdown voltage modeled in *ATLAS*?

A: Modeling of the increase in breakdown voltage at elevated temperatures requires a model to describe the temperature dependence of the impact ionization coefficients. In ***ATLAS*** there are two impact ionization models that include lattice temperature dependence. They are the Crowell-Sze model[1] called using the command IMPACT CROWELL and the Selberrherr Model[2] called using the command IMPACT SELB.

Users do not need to explicitly turn on any temperature dependent model. The impact ionization coefficients are always calculated based on the local lattice temperature. The temperature dependence is identical whether the lattice temperature is a uniform elevated temperature set using MODELS TEMP=<value> or if the simulation includes lattice heating in ***Giga***.

An excellent recent paper by Valdinoci et al [3] reports on a measurement technique to calibrate such models by measuring diode breakdown at constant elevated temperatures up to 400 °C. This paper proposes a new model which might be prototyped in ***ATLAS*** via the C-Interpreter. However it is informative to compare the reported measured data with the default models in ***ATLAS*** and then to apply tuning to attempt to match the measurements.

Measurements are reported in [3] for p+/n-well diode breakdown at temperatures from 293K to 473K. The doping profile of the diode was estimated from the room temperature breakdown voltage. Simulations were then run with the default coefficients for IMPACT SELB and IMPACT CROWELL. Results are shown in Figure 1.

The results show the Crowell model does not match the temperature dependence of breakdown voltage. In fact the results match closely those reported in [3] for the same model. The default IMPACT SELB results show a better match but under-estimate the effect of temperature on impact ionization by a significant amount. Clearly from the trends of the results, this discrepancy can be expected to grow at even higher temperatures.

By applying the following tuning parameters to the SELB model, it was possible to closely match the experimental breakdown versus temperature data.

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IMPACT MATERIAL=Silicon SELB  A.NT=0.3 \
B.NT=0.248 M.ANT=1.0 M.BNT=1.0
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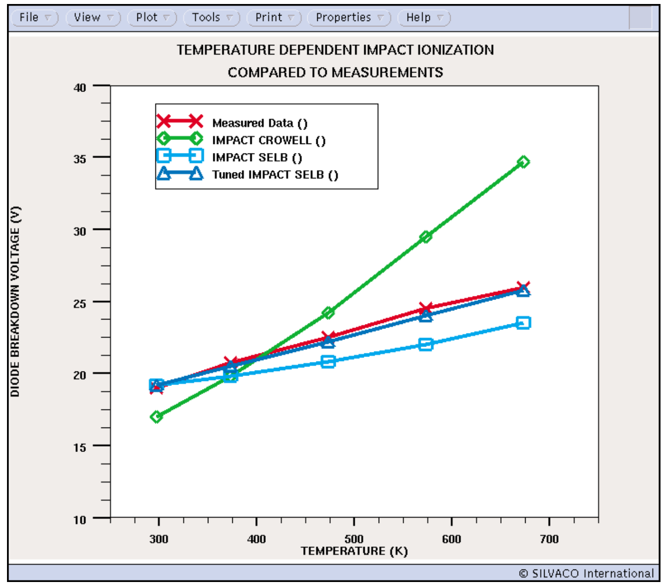

Figure 1. Comparison of default and tuned models in ***ATLAS*** to measured data for breakdown voltage vs. temperature.

Although this calibration is purely empirical, it is useful to fit measured data with the minimum of changes to the existing models. Typically users require only very minor calibration to fit room temperature breakdown voltages. Moving to a completely new model for temperature dependent ionization rates might require recalibration of the room temperature results so re-tuning of existing models a first option.

References

[1] C.R. Crowell, S.M. Sze, “Temperature Dependence of Avakanche Multiplication in Semiconductors”, Applied Physics Letters 9, pp. 242-244, 1966.

[2] S. Selberherr, “Analysis and Simulation of Semiconductor Devices”, Springer-Verlag, Wien-New York. 1984.

[3] Valdinoci et al. “Impact Ionization in Silicon at larg operating temperature”, SISPAD 1999.