

Recent Advances in Numerical Device Simulation

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Recent development of our numerical device simulator MINIMOS involves modifications to the transport model to account more appropriately for carrier heating. The Poisson equation and the continuity equations for electrons and holes are "the" established basic equations which are in use in anybody's simulator. However, the current relations for electrons (1) and holes (2) include the quantities Ut_n and Ut_p which are the electronic voltages for electrons and holes, respectively.

$$\vec{J}_n = -q \cdot \mu_n \cdot (n \cdot \text{grad } \psi - \text{grad } (Ut_n \cdot n)) \quad (1)$$

$$\vec{J}_p = -q \cdot \mu_p \cdot (p \cdot \text{grad } \psi + \text{grad } (Ut_p \cdot p)) \quad (2)$$

By setting the electronic voltages equal to the thermal voltage $Ut_o = \frac{k \cdot T_o}{q}$ and assuming the classical Einstein relations $D_n = \mu_n \cdot Ut_o$ and $D_p = \mu_p \cdot Ut_o$ one would obtain the conventional current relations. It has to be noted that simply waiving the classical Einstein relations and modeling carrier mobilities and carrier diffusivities independently is not equivalent to using the current relations (1) and (2).

These new current relations constitute only an improvement if consistent models for velocity saturation. There is only one set of consistent models based on integration of the Boltzmann transport equation over the momentum space. Just as brief summary about the electronic voltage our model can be conveniently written as a function of mobility (3).

$$Ut = Ut_o + \frac{2}{3} \cdot \tau_\epsilon \cdot v_{sat}^2 \cdot \left(\frac{1}{\mu_{LISF}} - \frac{1}{\mu_{LIS}} \right) \quad (3)$$

τ_ϵ denotes the energy relaxation time which is assumed to be a constant. This is no real restriction for silicon as confirmed by Monte-Carlo simulations. μ_{LIS} denotes the mobility due to lattice, impurity and surface scattering and μ_{LISF} includes additionally the mobility reduction caused by velocity saturation. One obtains the conventional transport model by assuming $\tau_\epsilon = 0$.

Additional enhancements include the capability of simulating in three space dimensions. Particular emphasis has also been laid on appropriately modeling the temperature dependence of physical parameters like the various scattering mechanisms and carrier generation/recombination.