Modeling of Impact Ionization by Consistent Monte Carlo and Hydrodynamic Models in Comparison with Measurements

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In this paper results on impact ionization from two different numerical silicon NMOS models – a hydrodynamic (HD) and a Monte Carlo (MC) model – are compared in detail. Moreover substrate currents resulting from both models are compared with measurements.

The MC model is the multiparticle model first reported in [1], which has been recently improved by incorporating the high energy band structure described in [2] and the impact ionization model [3] being consistent to the high energy band structure. Moreover for improving statistics in lowly populated device regions a real space version of the multiple refresh algorithm first introduced in [3] has been employed. The HD model is based on the set of equations of the generalized HD model derived in [4], but its parameters have been extracted from the improved MC model and not from the more conventional MC model used in [4] for parameter extraction. Using the spatial electrostatic potential and electron density distributions resulting from this (generalized) HD model, impact ionization is evaluated by the nonlocal lucky electron (LE) postprocessor model as published in [5] without changing any parameter of this model.

Impact ionization coefficients from the MC and LE models agree in homogeneous material and field for a wide range of field strength as shown in figure 1. This good agreement over a wide range of field strength could be achieved by scaling the impact ionization scattering rate in [3] by one global constant prefactor only, without changing the functional form of this rate in $\vec{k}$-space.

The models are compared for an NMOS device with $L_{Poly} = 0.875\mu m$ fabricated in the technology described in [6]. As can be seen in figure 2, simulated $I_D(V_G)$ and $I_{Sub}(V_G)$ characteristics for $V_D = 6V$ and $V_{Sub} = 0V$ resulting from both models are in good agreement with each other and with the measurements. The agreement of spatial distributions of electrostatic potential, electron density amd electron temperature resulting from both models is of the same quality as previously reported in [4]. Therefore in this paper this agreement is only exemplified in figure 3 for the electron density at one bias point. The close agreement of spatial impact ionization distributions resulting from the MC and HD(LE) models is shown in figures 4,5 and 6 for $V_G = 1.5V$, $3V$ and $5V$, respectively.

This agreement verifies again the conclusion already drawn in [5] that the HD(LE) model is well suited for a predictive modeling of hot electron effects.

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References

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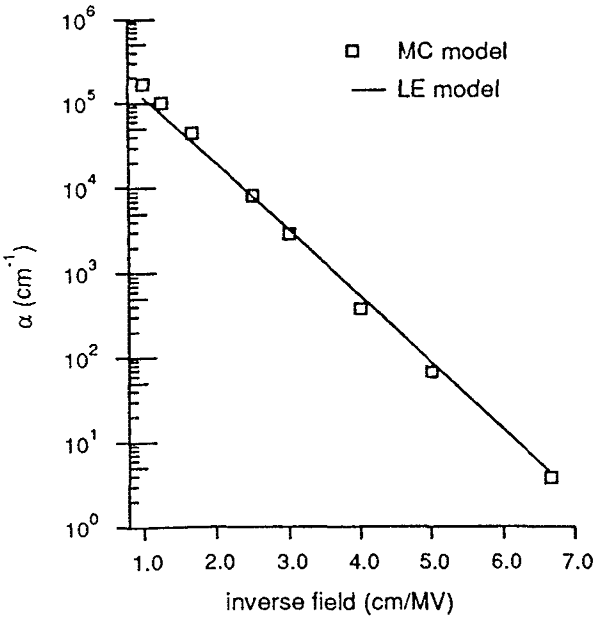

fig. 1: Bulk impact ionisation coefficients versus inverse field

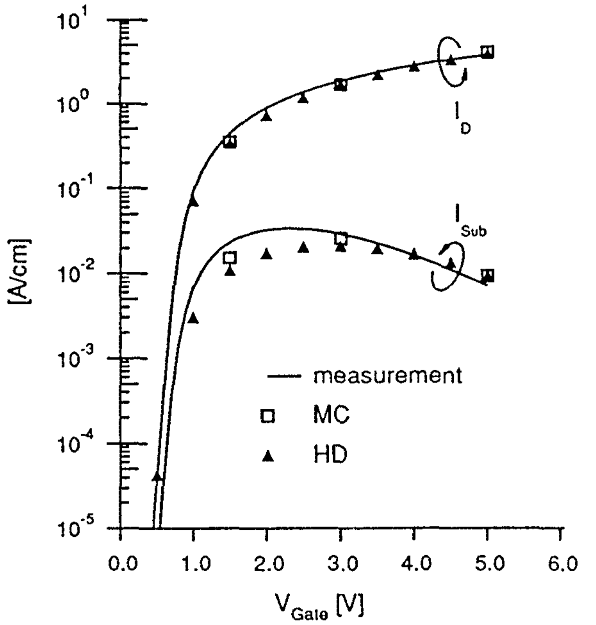

fig. 2: Comparison of measured and simulated drain and substrat current

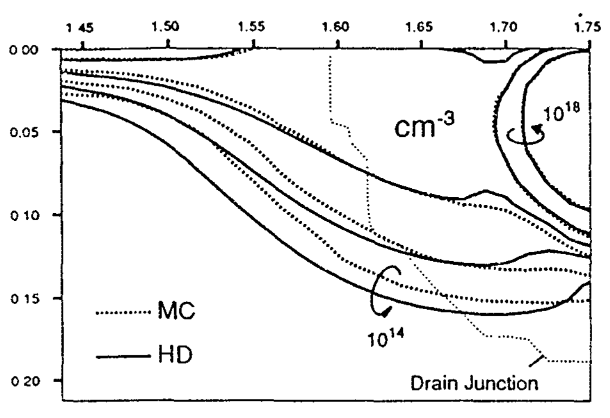

fig. 3: Comparison of electron density distributions near the drain region (V_G=1.5V)

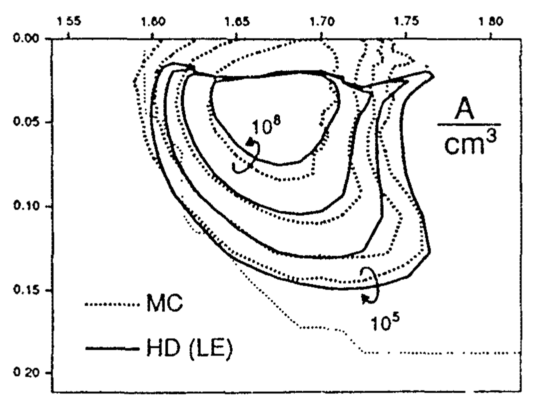

fig. 4: Comparison of impact ionisation rates near the drain region (V_G=1.5V)

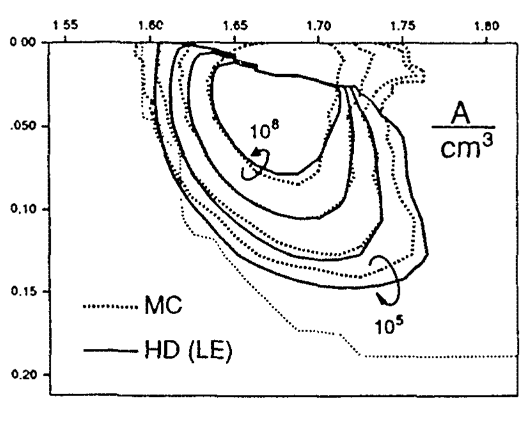

fig. 5: Same as figure 4 but V_G=3V

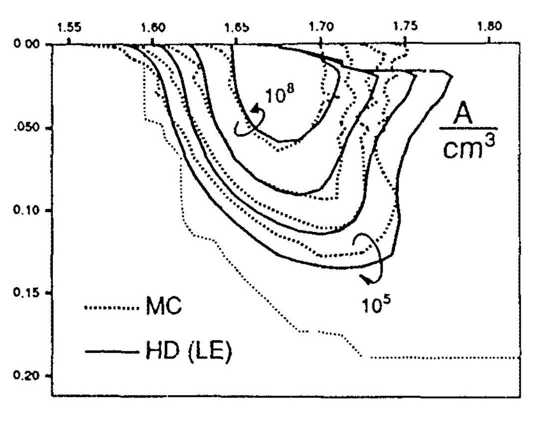

fig. 6: Same as figure 4 but V_G=5V