Revision of the Standard Hydrodynamic Transport Model for SOI Simulation

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***Abstract*—Anomalous output characteristics are observed in hydrodynamic simulations of partially depleted SOI MOSFETs. The effect that the drain current reaches a maximum and then decreases is peculiar to the hydrodynamic transport model. It is not observed in drift-diffusion simulations and its occurance in measurements is questionable. An explanation of the cause of this effect is given and a solution is proposed by modifying the hydrodynamic transport model.**

***Index Terms*—Device simulation, hydrodynamic transport model, numerical analysis, semiconductor device modeling, SOI MOSFET.**

I. Introduction

USING the standard hydrodynamic (HD) transport model for simulation of partially depleted SOI MOSFETs, an anomalous decrease of the drain current with increasing drain–source voltage has been observed (Fig. 1).

The anomalous effect has been reproduced using the two different device simulators MINIMOS-NT [1] and DESSIS [2] and can be explained by an enhanced diffusion of channel hot carriers into the floating body [3], [4]. It is believed that this decrease in drain current is an artifact because experimental data do not show this effect, nor can it be observed when using the drift-diffusion (DD) transport model. One exception is given in [5], where a weak decrease of the measured drain current of a p-MOS SOI is reported.

However, applicability of the HD model to the ever downscaled devices is desirable, because in contrast to the DD model it takes nonlocal effects into account. Empirical measures provided by DESSIS, such as weighting heat flow and thermal diffusion, have only little influence on the current drop. It is assumed that the anomalous current drop is a consequence of several physical assumptions usually made in the derivation of the standard HD model. We present a modified HD model, which accounts for an anisotropic carrier temperature and a non-Maxwellian distribution function. This new model is implemented in MINIMOS-NT and gives proper results for partially depleted SOI MOSFETs. The additional model parameters are estimated from Monte-Carlo (MC) calculations.

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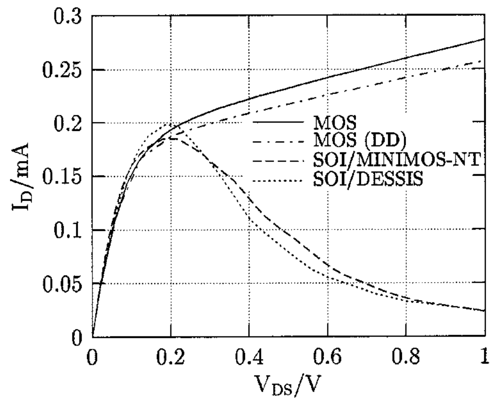

Fig. 1. Output characteristics obtained by standard DD and HD simulations verified by using two different device simulators.

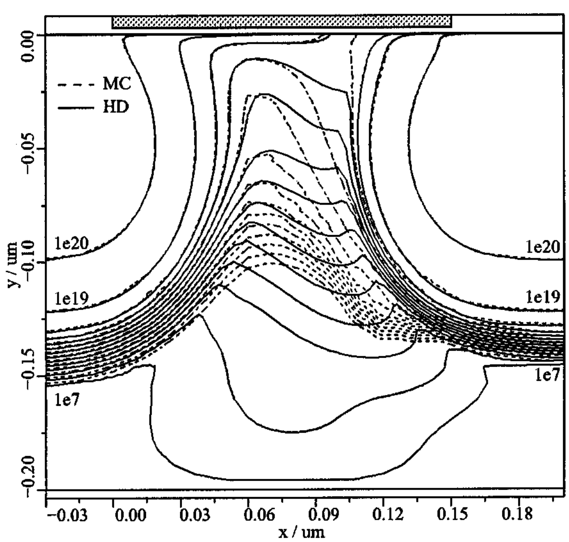

Fig. 2. Electron concentration in an SOI MOSFET obtained by HD and MC simulations.

II. The Anomalous Simulation Effect

The energy balance equation represents the main difference between the HD and the DD transport model. The benefit of the increased computational effort of solving an additional equation with the HD model is that the carrier temperature can differ from the lattice temperature. Since the diffusion of the carriers is proportional to their temperature, the diffusion can be significantly higher with the HD transport model. Fig. 2 clearly shows the enhanced vertical diffusion of electrons as compared with the DD result in Fig. 3.

When simulating SOI MOSFETs, this increased diffusion has a strong impact on the body potential because the hot electrons