Bridging the Gap between the Hydrodynamic and the Monte Carlo Model

- An Attempt -

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In the literature there are two different approaches to describe high energy transport in silicon, namely the Hydrodynamic (HD) /1/ and the Monte Carlo (MC) /2/ model. The MC model allows the incorporation of a nonparabolic band structure according to the real density of states (fig.1). On the other hand the derivation of the HD model is usually based on the constant effective mass approximation. Frequently this is considered as an inherent drawback of the HD model.

Often large discrepancies are found if the electron temperatures resulting from both models are compared in a straight forward manner. This is demonstrated in fig.2 and fig.3, where it can be seen that the temperatures resulting from the mean energy simulated by the MC model /3/ are about a factor of 2 larger than the respective temperatures resulting from GALENE /4/. Nearly the contrary result is reported in /5/ (there energies resulting from the MC model are smaller by about a factor of 2), thus enhancing the confusion even further. As already indicated in the first section it is a common opinion that the HD model is based on less solid theoretical grounds than the MC model. Therefore the discrepancies found, were often believed to be due to the inherent deficiencies of the HD model.

It will be shown that the discrepancies between the two approaches can be reduced. The equations of the HD model can be derived without assuming the effective mass approximation. From this derivation a guideline can be extracted which shows how to compare both models in a consistent manner.

Key features of this new treatment are generalized definitions of relaxation times and electron temperature. A comparison of the MC model and the HD model will be presented, where the newly defined relaxation times are incorporated in the HD model and the newly defined electron temperature is used for the comparison.

References:

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/3/ H.J.Peifer et al., presented at "1988 VLSI Process/Device Modeling Workshop", Tokyo, Aug. 1988
/4/ B.Meinerzhagen et. al., IEEE Trans. on ED, vol.35, pp.689-697, 1988
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/6/ M.V.Fischetti et al., Phys. Rev. B, vol.38, pp 9721-9745, 1988

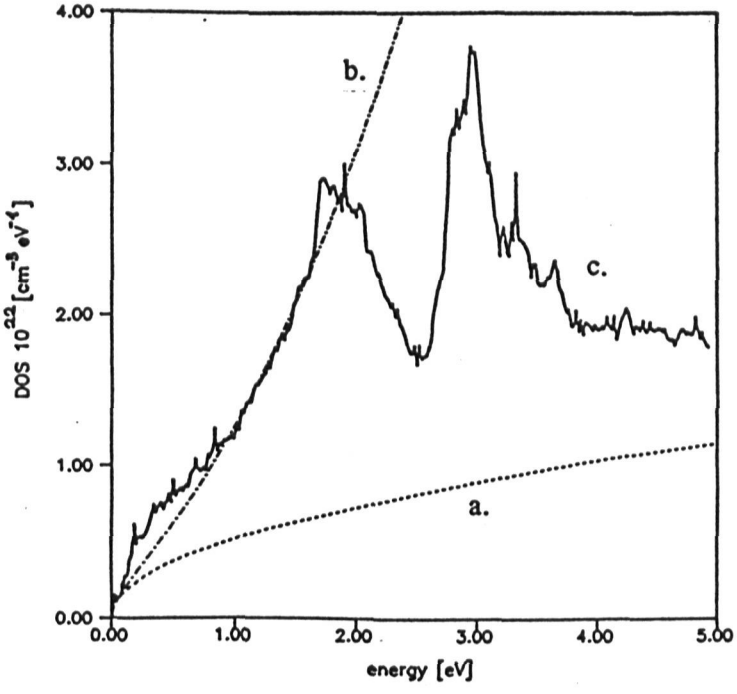

Fig. 1:

density of states for silicon

a.) parabolic band approximation
b.) nonparabolic band approximation
c.) band structure from pseudopotential calculation /6/

Fig. 2:

electron temperature (K) defined by $\langle \epsilon \rangle = {}^3/_2 k_B T$ near the drain junction for an n-channel sub-μ LDD-MOSFET structure resulting from the MC model.

(V_S=V_B=0V, V_D=5V, V_G=1.5V)

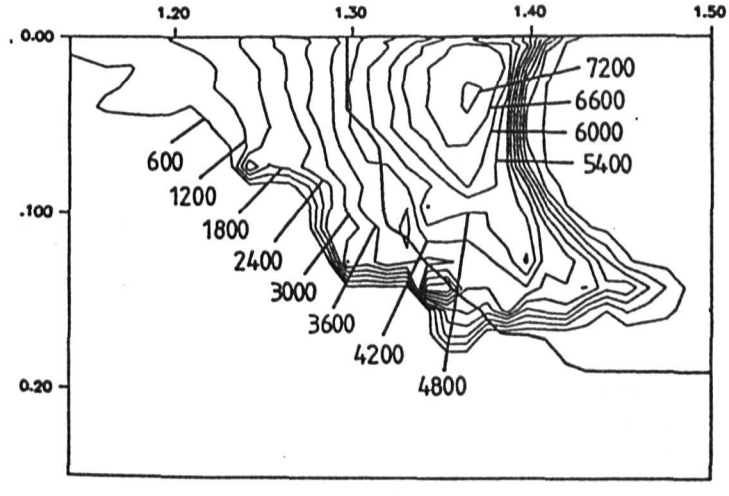

Fig. 3:

electron temperature (K) resulting from the HD model (GALENE) for the same device and identical bias condition as in fig.2.