Hydrodynamic Model for Silicon Carbide Semiconductors including crystal heating

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The recent considerable advances have allowed Silicon (Si hereafter) semiconductor technology to approach the theoretical limits of this material. Moreover, advanced optoelectronic and microelectronic devices, as well as of power devices cannot be handled by the present Si-based devices, e.g. higher blocking voltages, switching frequencies, efficiency, and reliability. To overcome these limitations, new semiconductors like Silicon Carbide (SiC hereafter) and compounds, with their superior electrical properties (such as wide band gap, high electron saturation velocity, high breakdown electric field, high thermal conductivity) are likely candidates to replace Si in the next future. The drift diffusion model currently available for SiC and compounds is not able to describe accurately the physics because it is based on fitting parameters and ad hoc assumptions on the transport coefficients and the constitutive equations, whose validity is often restricted to specific devices and regimes close to thermodynamic equilibrium. The kinetic theory is a powerful tool to understand transport phenomena of charged particles at a mesoscopic level. This theory is the natural framework to describe off-equilibrium phenomena in sub-micrometric semiconductor devices, where the onset of high electrics fields, the influence of the thermal heating of the carriers and crystal lattice on the performance of semiconductor devices increase as the miniaturization is more aggressive and the density of the transistor grows. The electrothermal transport can be described by using the Bloch-Boltzmann-Peierls (BBP) kinetic equations for the phonon and the electron distribution functions, with the appropriate collisional operators [1]. Since the solution of these kinetic equations is generally an uneasy task, by using the moment method, we have introduced a new hydrodynamic model where all the main interactions between electrons and phonons, as well as the scatterings of phonons among themselves are considered. By taking advantage of the Maximum Entropy Principle [2, 3], the constitutive equations for such material have been determined without any need of introducing ad hoc approximations or phenomenological coefficients. Simulation results for bulk SiC have been obtained, proving the consistency of the model. In particular the overheating of the sample has been predicted as function of the simulation time, and these simulation results will be shown at the conference.

References

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