An extended fluid-dynamical model describing electron transport in semiconductors

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Abstract- Because of the presence of very high electric fields, an accurate description of the electric and thermal behaviour of modern electron devices requires more sophisticated mathematical models than the standard drift-diffusion ones. Therefore generalisations of these models have been sought which incorporate more dynamical variables in order to be able to describe situations more critical than quasi-stationary ones.

These extended models are usually obtained as macroscopic approximations of the Boltzmann transport equation (BTE) which determines the time evolution of the electron distribution function $f(\vec{x}, t, \vec{k})$, taking into account the electric field $\vec{E}$ acting on the electrons and, through the collision operator $Q(f)$, the collisions among electrons and phonons and impurities or among electrons themselves. One way of obtaining coherent macroscopic models starting from the BTE is based on the use of the moment method and the maximum entropy principle in the framework of rational extended thermodynamics. In this work, by using these tools, we find a consistent, non-linear fluid dynamical model describing electron transport in semiconductors, which is free of any fitting parameter and makes use, as fundamental variables, of the moments of the distribution function up to the third tensorial order. That is the first 20 moments: electron number density, mean velocity, momentum flux and flux of the momentum flux.

To test this model we have considered the case of bulk silicon in stationary, homogeneous conditions, solved the resulting equations (for 2 values of the lattice temperature: $77K$ and $300K$) and compared the results with those obtained by using other models. We have also validated the obtained constitutive relations by means of a direct comparison with Monte Carlo data.