An anisotropic hydrodynamical model for charge transport in semiconductors

Giovanni Mascali

Department of Mathematics and Computer Science, University of Calabria and INFN-GRUPPO c. Cosenza, Arcavacata, Italy

In semiconductors, the charges mainly contributing to current are the electrons which occupy states around the minima of the lowest conduction bands and the holes around the maxima of the highest valence bands [1]. Therefore it is fundamental to build models which make use of the best possible approximations of the energy dispersion relations for those charges. Here we present a hydrodynamical model using the following expression for these relations

\[ \mathcal{E}(k) = \frac{\hbar^2|k|^2}{2m_e} \gamma(\mathcal{E}) \psi^{-1}(n), \] (1)

which comprehends as particular cases both the Kane ellipsoidal approximation and the warped one, depending on the choice of the angular factor \( \psi \). In the formula, \( \mathcal{E} \) is the charge energy, \( k \) is the charge wave vector, \( m_e \) is the free electron mass, \( \gamma \) is the non-parabolicity factor, \( n := \frac{k}{|k|} \), and \( \hbar \) is the reduced Planck constant. The hydrodynamical model is obtained starting from the Boltzmann transport equations for each charge population, taking the moments of these equations and closing the resulting macroscopic equations by means of the maximum entropy principle. All the main scattering mechanisms, electrons undergo in semiconductors, can be taken into account, and therefore the model can be used to describe the electrical behavior of both the elemental and the compound semiconductors. In particular we have used it to simulate bulk 4H and 6H-SiC. The results relative to the average electron velocity for these two materials are reported in Figure 1, where it is shown that the dependence on the electric field direction is correctly predicted by the model.


Figure 1: Total velocity vs the applied electric field for 4H and 6H-SiC along the principal directions