Hot Electron Distribution Function for the Boltzmann Equation with Analytic Bands

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The shape of the electron energy distribution (EED) is of paramount importance in order to predict disruptive phenomena in semiconductor devices. Monte Carlo simulations with parabolic bands prove that the EED tail is maxwellian [1], [2], and several analytic euristic models have been introduced for modeling the EED in the bulk case [3], [4]. Starting form the Bolzmann transport equation in the bulk case, with quasi parabolic band, scattering with impurities, acoustic and optical phonons, we prove analytically that its EED, for large values of the energy ε, is of the following type

$$f(\varepsilon) \simeq \exp\left[-r(2\varepsilon)^{\frac{s}{2}}\right] \qquad (1)$$

where r and s are some positive constants. In order to obtain this result, we introduce the functionals

$$\mathcal{F}_{r,s}(f) = \int_{\mathbb{R}^3} f(\mathsf{k}) \exp\left[r(2\varepsilon)^{\frac{s}{2}}\right] d\mathsf{k} \qquad (2)$$

which indicate that the solution of the BTE have high-energy tails given by eq.(1). By expanding the exponential function in (2) into Taylor series we obtain (formally):

$$\begin{aligned} \mathcal{F}_{r,s}(f) &= \int_{\mathbb{R}^3} f(\mathsf{k}) \left(\sum_{n=0}^{\infty} \frac{r^n}{n!} (2\varepsilon)^{\frac{sn}{2}} \right) d\mathsf{k} = \\ &= \sum_{n=0}^{\infty} \frac{m_{\frac{sn}{2}}}{n!} r^n \end{aligned} \qquad (3)$$

where m_p are the *symmetric moments* of the distribution function. The maximum value $r_s^\star$ of r, for which the power series (3) converges, is its radius of convergence, and the order of the tail s is the value for which the series has a positive and nite radius of convergence. By using suitable moments estimate based on the BTE, we are able to prove that $r_s^\star$ is nite, for some s $\geq$1. However this method does not give any information about the numerical values of r and s, which could be determined by MC simulations. These simulations show that the high-energy tail depends on the band structure. In fact in the parabolic band approximation the tail is maxwellian (i.e. $s = 2$) where $1/r_s^\star$ is not the lattice temperature, but a function of the electric eld, as shown in gure 1. In the quasi parabolic case, MC simulations show that s is not a constant but a function of the electric eld, as well as $1/r_s^\star$.

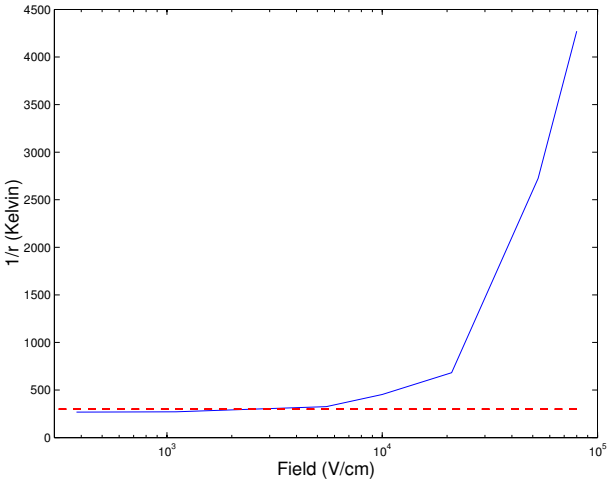

Fig. 1. The parameter 1/r in eq.(1) with s =2, as function of the electric eld, in the parabolic band approximation. The dashed straight line indicates the lattice temperature 300 K .

REFERENCES

[1] A. Abramo, C. Fiegna, J. Appl. Phys. **80** , 889–893, (1996)
[2] C.C.C. Leung, P.A. Childs, Appl. Phys. Lett., **66**(2), 162–164, (1995)
[3] D. Cassi and B. Riccò, IEEE Trans. Elec. Dev., **37**, 1512,(1990)
[4] T. Grasser, H. Kosina, C. Heitzinger and S. Selberherr, J. Appl. Phys., **91**, 3869,(2002)

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