Carrier Transport Analysis in Bulk Silicon Based on Carrier Distribution Evolutions

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Momentum space electron distributions in bulk silicon are calculated by the direct integration of Boltzmann transport equation, similar to that employed in ion implantation analysis.[1)] This approach is featured by transacting carrier population between discretized states in k-space, following transition rates based on physical events such as drift and phonon scattering.

Distribution details are revealed because this method allows easier access to carrier distribution itself than the Monte Carlo method does. The evolutions of distributions and the steady state profiles are explained by the existence of lucky electrons, energy dependent scattering rates, and the isotropic nature of intervalley phonon scattering.

These analyses would offer a basic background wherein hot carrier related phenomena, such as gate current, substrate current, and impact ionization, can be investigated without using any a priori distribution function but by exploiting the higher energy tail of carrier distribution.

Ref. 1) L.A. Christel, J.F. Gibbons and S. Mylroie, J. Appl. Phys, 51, 6176(1980).

Fig.1. Evolutions of k-space distribution (for the parabolic band)

Distribution contour maps are displayed for t=0 (equilibrium in the lattice), t=0.16psec (at the velocity overshoot) and t=2psec (at the quasi-steady state), respectively. Lines are drawn down to two orders less than the peak height.

Fig.2. Steady state distribution for various field strengths (for the parabolic band)

Fig.3. Energy distribution

The energy distribution (considering the nonparabolic band) and the drifted Maxwellian distribution (inherently assuming the parabolicity) are plotted. Both distributions are represented by the same drift velocity and the mean energy. However, the higher energy tails are quite different from each other, which causes an incorrect evaluation of hot carrier related phenomena.

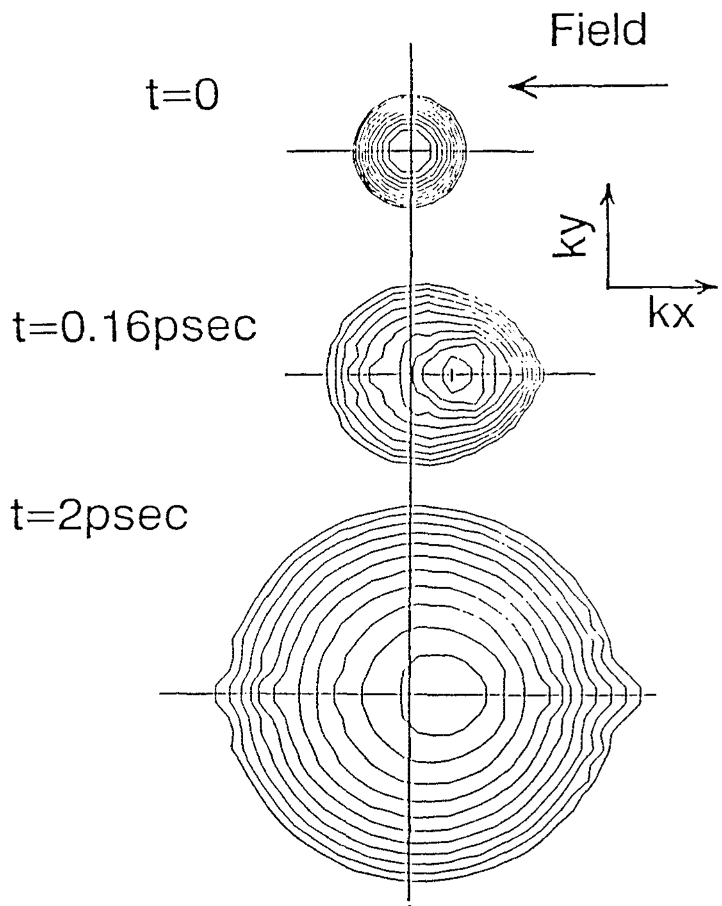

Fig.1. Contour maps of carrier distribution in k-space at 5.E+06V/m, 300K

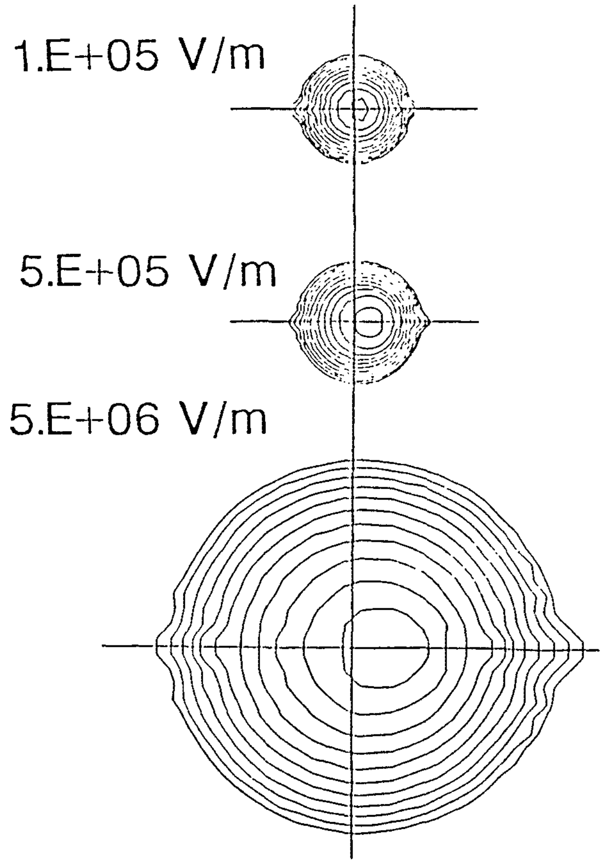

Fig.2. Steady state distribution at 300K

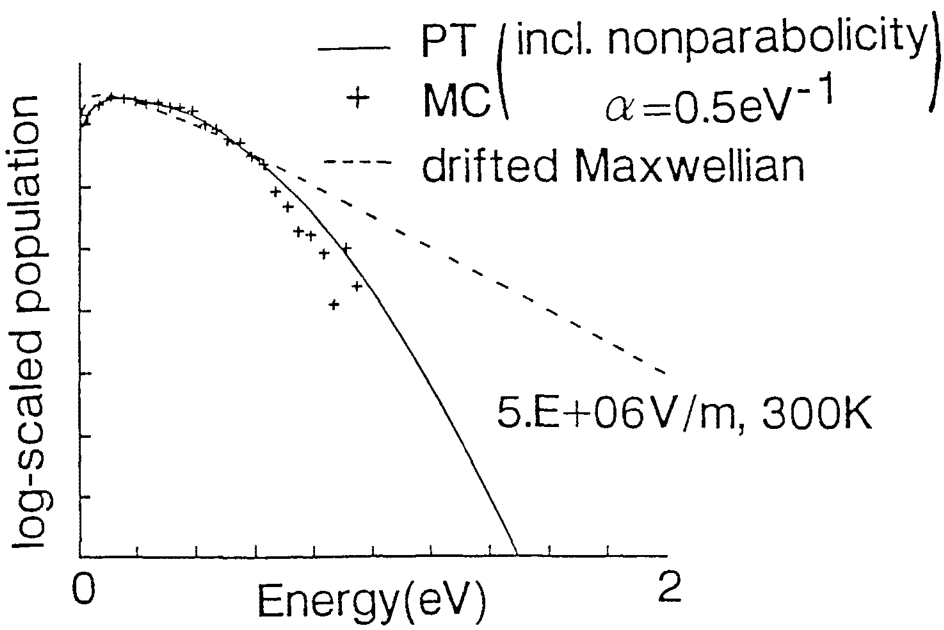

Fig.3. Energy distribution (steady state)