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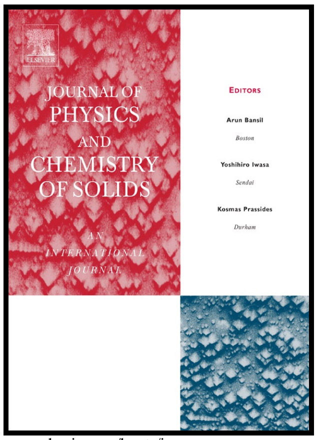

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A realistic analysis of the phonon growth characteristics in a degenerate semiconductor using a simplified model of Fermi-Dirac distribution

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Abstract

The phonon growth characteristic in a degenerate semiconductor has been calculated under the condition of low temperature. If the lattice temperature is high, the energy of the intravalley acoustic phonon is negligibly small compared to the average thermal energy of the electrons. Hence one can traditionally assume the electron-phonon collisions to be elastic and approximate the Bose-Einstein (B.E.) distribution for the phonons by the simple equipartition law. However, in the present analysis at the low lattice temperatures, the interaction of the non equilibrium electrons with the acoustic phonons becomes inelastic and the simple equipartition law for the phonon distribution is not valid. Hence the analysis is made taking into account the inelastic collisions and the complete form of the B.E. distribution. The high-field distribution function of the carriers given by Fermi-Dirac (F.D.) function at the field dependent carrier temperature, has been approximated by a well tested model that apparently overcomes the intrinsic problem of correct evaluation of the integrals involving the product and powers of the Fermi function. Hence the results thus obtained are more reliable compared to the rough estimation that one may obtain from using the exact F.D. function, but taking recourse to some over simplified approximations.

Keywords: Model distribution, Phonon growth, Degenerate semiconductor, Low temperature

I. Introduction

An electron ensemble in a semiconductor when subjected to a relatively high electric field, may be significantly perturbed from the state of thermodynamic equilibrium and then, the material may exhibit electrical non-linearity. The prevalent experimental conditions determine the field at which the non-linearity may set in. For example, n-Ge or InSb may exhibit non-linearity at low lattice temperatures $T_L \leq 20K$, even for a field of a fraction of a V/cm.

It is well known that the interaction of the electrons with the impurities is elastic, and when the lattice temperature is low, say around 20K or less, the interaction with the intravalley acoustic phonons predominantly take part in the process of energy balance of the electron-phonon system. In such a perturbed state, the non-equilibrium electrons attain an effective temperature T_e, that exceeds the lattice