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ON SOME ASPECTS OF ELECTRONIC TRANSPORT CHARACTERISTICS OF SEMICONDUCTOR STRUCTURES AT LOW LATTICE TEMPERATURES.

ABSTRACT

In this thesis, we examine a compensated, non-degenerate compound semiconductor subjected to a relatively high electric field at low lattice temperatures. The impact of inelastic interactions between non-equilibrium electrons and neutral impurities, specifically through excitation and ionization processes, on the net energy loss of an electron has been analyzed to determine the electrical transport coefficients.

The study focuses on the electrical transport properties of a non-degenerate ensemble of electrons in a bulk compound semiconductor under the condition of a high applied electric field and low lattice temperature. Due to the complexity of the Boltzmann transport equation, an exact analytical solution is usually not feasible without employing certain approximations. These approximations, however, can often limit the theoretical results' validity across a significant range of experimental conditions. Therefore, an approximate analysis of high-field transport properties is presented, assuming a heated Maxwellian energy distribution for non-equilibrium electrons, with a field-dependent effective electron temperature. This approach is valuable as it provides data that are often useful for device technologists.

The electrical transport characteristics of a non-equilibrium ensemble of three-dimensional electrons in a bulk structure are obtained, taking into account important low-temperature effects that are often overlooked for mathematical simplicity. These include the non-degeneracy of the carrier ensemble, the inelastic nature of electron-phonon interactions, and more. Key electronic interactions considered at low lattice temperatures include deformation potential acoustic phonon scattering, piezoelectric acoustic phonon scattering, and scattering by ionized and neutral impurities.

This work addresses several aspects of electronic transport, including (i) the effective electron temperature characteristics of the electron ensemble, (ii) the energy loss rate and non-ohmic mobility of the electrons, and (iii) the efficiency of second harmonic generation of microwave signals due to the electrical nonlinearity of the electron ensemble.

Numerical results for transport coefficients are presented for three-dimensional ensembles of electrons in the compound semiconductors InSb, InAs, and GaSb, across different lattice temperatures. These results are compared with available experimental and theoretical data. The thesis also discusses the applicability and limitations of the theory in detail and suggests avenues for further refinements.

Souma Saha, 11.09.2024.

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