ELECTRON-ELECTRON AND ELECTRON-IMPURITY SCATTERING AND THEIR EFFECTS ON THE PROPERTIES OF SEMICONDUCTOR SUPERLATTICES

SUMMARY OF THE THESIS
TO BE SUBMITTED FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN
PHYSICS
TO
M.S. UNIVERSITY OF BARODA, VADODARA

AUGUST 1999

UNDER THE GUIDANCE OF :
Dr. A. C. SHARMA
M.S. UNIVERSITY OF BARODA,
VADODARA-390 002.

BY
PUSHPENDRA TRIPATHI
M.S. UNIVERSITY OF BARODA,
VADODARA-390 002.

SUMMARY

A theoretical study on relaxation time for electron-impurity in doped superlattices and for electron-electron scattering in compositional superlattices of type-I as well as type-II, coupled plasmon-phonon modes and their line shapes in type-II compositional superlattice, and damping of collective excitations in doped superlattice is presented in this thesis. The thesis work is divided into four chapters. Chapter-I consist of an introduction to various types of semiconductor superlattices and a review work on the aspects of superlattices which have been studied by us. Chapter starts with a brief introduction to semiconductor compositional superlattices, doped superlattices and strained superlattices. A review on the recent theoretical and experimental work done on plasmon-phonon coupled modes and magnetoplasmons in superlattices is given thereafter. Experimental and theoretical studies carried out in recent years on light scattering in superlattices and the work done on electron-electron and electron-impurity scattering are also reviewed in this chapter. Electron-electron scattering plays a major role in many of the physical processes such as tunneling, ballistic transport and weak localisation.

The brief summary of work presented in chapters-II to IV is as follows:

In chapter-II, we reported our theoretical investigations on frequencies and damping rates of oscillations of coupled electron-hole plasma in a doped GaAs superlattice. The real part of a complex zero of dielectric response function describes the plasma frequency, whereas imaginary part of it yields the damping rate. Strong scattering of charge carriers from random impurity potentials in a doped GaAs superlattice gives rise to a large value of damping rate which causes over-damping of plasma oscillations of coupled electron-hole gas below q_c, a critical value of wave vector component (q) along the plane of a layer of electrons (holes). The plasma oscillations which correspond to electrons gas enter into over-damped regime for the case of weak coupling between layers. Whereas, plasma oscillations which belong to hole gas go to over-damped regime of oscillations for both strong as well as weak coupling between layers. The damping rate shows strong q-dependence for $q < q_c$, whereas, it weakly depends on q for $q \geq q_c$. The damping rate exhibits a sudden change at $q=q_c$, indicating a transition from non-diffusive regime (where collective excitation can be excited) to diffusive regime (over-damped oscillations)

Chapter-III, incorporates our theoretical study on coupled plasmon-phonon modes in a compositional superlattice of type-II. The dielectric function and the density–density correlation function are calculated for a compositional superlattice of type II, which consists of alternate electron and hole layers (a two–component plasma) in an inhomogeneous dielectric background. The dielectric background of the electron gas is considered to be different from that of holes and the finite width of an electron (hole) layer is considered to allow both intrasubband and intersubband transitions. Our model superlattice consists of electron plasma, hole plasma, lattice vibrations of the background of the electron gas and lattice vibrations of the background of the hole gas. Electron–electron, electron- hole, hole – hole, electron–phonon, hole–phonon, and phonon–phonon interactions take place in our model superlattice. Our calculation is applied to the $In_{1-x}Ga_xAs/GaSb_{1-y}As_y$ superlattice. Variation of plasmon-phonon coupled modes and their lineshapes with (x, y) and unit cell width has been investigated in order to study the effects of semiconductor to semimetal or vice versa phase transitions. It is found that phase transition prominently affects the plasmon modes, while phonon modes remain almost unaffected. The inhomogeneity in the background of the electron–hole gas also produces a significant change in plasma frequencies. Lineshapes of coupled palsmon–phonon modes for both semimetal and semiconductor phases are calculated and are computed with those of the homogeneous background. Significant changes in peak height and half width are observed due to inhomogeneity in the dielectric background and the semiconductor to semimetal phase transition.

Our theoretical investigations on relaxation time for a charge carrier scattering from other charges are given in chapter-IV. We have calculated transport relaxation time for an electron ; (i) due to electron-electron scattering in a type-I superlattice and (ii) due to electron-electron and electron-hole scattering in a type-II superlattice, using Fermi-golden rule. The transport relaxation time for a hole due to hole-hole and hole-electron scattering in type-II superlattice is also calculated. Only electron-electron scattering takes place in a type-I superlattice, whereas electron-electron, hole-hole and electron-hole (hole-electron) scattering processes occur in a type-II superlattice. As compared to two-dimensional electron gas, both intralayer and interlayer interactions between charge carriers in a superlattice contribute to transport relaxation time. It is shown that both large momentum transfer scattering as well as small momentum transfer scattering processes contribute to transport relaxation time at all values of temperature and carrier densities. The transport relaxation time of a charge carrier in a superlattice is found larger than that in a three-dimensional free electron gas. The transport relaxation time is found to decrease on increasing temperature, carrier density and single particle energy in sperlattice. We also find that the scattering processes weaken on increasing the width of layer consisting of electrons (holes). The electron-hole (hole-electron) scattering process shows maximum contribution to the transport relaxation time when a hole layer lies exactly in between two consecutive electron layers in a type - II superlattice.

Guiding Teacher
(Dr. A.C. Sharma)

Reader in Physics

Place : Baroda

16/8/99
Research Student
(Pushpendra Tripathi)