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لم ترد بالاصل

Electrical Properties of Te-Doped n-Type InSb At Low Temperatures

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ABSTRACT

Abstract

Measurements of the longitudinal and transverse direct current (dc) magnetoresistance of moderately doped n-InSb samples were carried out as a function of (i) temperature, T, down to 18 K and (ii) magnetic field up to 4.8 kG. Three different conduction mechanisms were observed.

The excess donor concentrations of the investigated samples were 9.5×10^{13} cm^{-3}, 1.5×10^{14} cm^{-3} and 1.7×10^{14} cm^{-3}. The average spacing between the donors was estimated and found to be in the order of the effective Bohr radius of this system (650 Å). The present concentrations, therefore, were assumed to be of a moderate type.

At low temperatures, in absence and presence of weak magnetic fields, the behaviour of the conductivity was of a metallic - like one, i.e., the conductivity σ tends to a finite value as $T \rightarrow 0$ K. However, at high magnetic fields, a metal-insulator transition might occur at a particular threshold value, H_c. This critical magnetic field depends on the concentration of the carriers. H_c, indeed, was found to increase as the concentration was increased. The presence of the magnetic field leads to a shrink in the electron wave functions associated with the different donors. The result is that ; at a particular field, H_c, the overlap of the adjacent wave-functions will be negligibly small so that the donors may become isolated. Hence, metal-insulator transition may occur. High concentrations, then needs high magnetic fields to induce such transition.

Measurements carried out at zero magnetic field in the ionized impurity scattering regime (low temperatures, below 50 K) show that the resistivity ρ varies with T as $\rho \sim T^{-a}$ where $a \sim 0.7$. This is less than the expected theoretical findings. This may be due to a possible contribution

of electron-phonon scattering at these temperatures. The transverse magnetoresistance in the ionized impurity scattering region in the direct vicinity of the quantum limit was discussed in terms of a recent model suggested by Murzin and Golovko (1991). In this case the contribution of the low-energy electrons to the transverse conductivity leads to a variation of the resistivity with T and H according to the form $\rho_{\perp} \sim HT^{-9/8}$ which is almost followed in the present study. The variation of the longitudinal magnetoresistance with both T and H was also considered.

At the intermediate temperature range, from about 145 K to about 50K, the main contribution to the resistivity comes from the electron-phonon scattering mechanism. In this case the conductivity is governed by the relation $\sigma = ne\mu$ (at zero magnetic field). The concentration of the carriers, n, is constant and the variation of σ with T comes from the temperature dependence of the mobility μ, thus $\sigma \sim T^b$. On the theoretical side b = -1.5, nevertheless the experimental observations showed that b ~ -1.1. The reduction of b below the theoretical prediction is suggested to be due to a possible effect of the ionized impurity scattering which leads to an opposite temperature dependence of ρ. The temperature and magnetic field dependence of both the longitudinal (ρ_{11}) and the transverse ($\rho_{\perp}$) resistivities were discussed in terms of the existing theories.

At the higher temperature range (above 145 K) the conductivity is mainly due to the familiar intrinsic behaviour and the exponential temperature variation of ρ was observed as $\rho \sim \exp(E_g/2k_BT)$. The band gap width E_g was calculated and found to agree with the theoretical one.

CHAPTER I

INTRODUCTION

1.1 General Features of Semiconductors

Transport properties of semiconductors have been of considerable interest over the last four decades from both experimental and theoretical points of view. The charge transport measurements in these materials provide information about the different types of the conduction mechanisms.

Semiconductors are substances in which the valence band (V.B) is completely filled with electrons, while the conduction band (C.B.) is partially filled with them at temperature T > 0. The width of the forbidden gap is not great (not exceed few electron volts). Semiconductors owe their name to the fact that the electrical conductivity takes an intermediate position between metals and dielectrics. Fig. (1.1).

Intrinsic and extrinsic (impurity) semiconductors could be distinguished according to their behaviour with temperature. The intrinsic semiconductors include chemically pure ones. The electrical properties of the impurity semiconductor are determined by the impurities they have been artificially doped with.

The electrical properties of semiconductors are greatly affected by the concept *of hole*. In an intrinsic semiconductor at absolute zero, all the levels of the V.B. are completely filled with electrons, while they are absent in the C.B, Fig. (1.2.a). Under normal conditions an electric field cannot transfer electrons from the V.B. to the C.B., therefore an intrinsic semiconductor behaves as a dielectric at absolute zero. At temperatures