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Pressure Dependence of the Carrier Concentrations in p-Type Alloys of $Hg_{1-x}Cd_xTe$ at 4.2 and 77 °K*

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Electrical transport measurements have been made on p-type samples of $Hg_{1-x}Cd_xTe$ with x near 0.15 at temperatures of 4.2 and 77 °K and at hydrostatic pressures up to 9 kbar. A sharp transition is observed in both the Hall coefficient and conductivity versus pressure at 4.2 °K. The pressure dependence of the carrier concentrations and mobilities has been obtained from magneto-Hall and magnetoresistance data. Analysis using $\vec{k}\cdot\vec{p}$ theory yields values for the Fermi energy, measured with respect to the valence-band edge, of more than 9 meV, which are independent of pressure. A possible model to account for this behavior is described. Magnetic freeze-out effects have been observed and attributed to the lowest-energy, spin-split, zero-order Landau level passing through the Fermi energy. A value of 7×10^{-6} eV/bar is obtained for the pressure coefficient of the energy gap at 77 °K. Non-Ohmic behavior has been observed at 4.2 °K during the magnetic freeze-out.

INTRODUCTION

A continuous range of $Hg_{1-x}Cd_xTe$ alloys can be formed between the semimetal HgTe and the semiconductor CdTe. The general features of the band structure are now well established (see review papers by Long and Schmit[1] and Harman[2]). HgTe is a semimetal with an inverted band structure, like that proposed for gray tin,[3] with a negative Γ_6-Γ_8 energy gap of 0.3 eV, at low temperature. The energy gap increases approximately linearly with x, going through zero for $x\simeq0.15$ at low temperature. At higher values of x the alloys are semiconducting with a band structure qualitatively like that of the direct-gap III-V compounds. A large number of investigations (see review papers for references) have established that the dispersion relation for the conduction band is well described by Kane's $\vec{k}\cdot\vec{p}$ model.[4] A recent determination[5] from magnetoreflection measurements yielded a value of 8.4×10^{-8} eV cm for the Kane matrix element.

The behavior of n-type $Hg_{1-x}Cd_xTe$ is now relatively well understood, but the valence-band parameters have yet to be established. Reported values for the heavy-hole mass range from $0.3m_0$ to $7m_0$,[5-11] and the band overlap energy in the semimetallic alloys, due to the warping of the heavy-hole band, has not been reliably determined. In general, the electrical transport properties of the p-type alloys have proved complex and difficult to interpret.[5,12-14]

The object of this work was to obtain information on the valence-band structure and on acceptor levels near the valence-band edge. Measurements of the electron and hole concentrations have been made on p-type, nearly zero-band-gap semiconducting samples, as the energy gap was opened up with hydrostatic pressure. Because of the high electron-to-hole mobility ratio the minority electrons can dominate the transport properties in the semimetallic state and large changes in the transport coefficients occur during the semimetal-semiconductor transition produced by applying pressure.

Hydrostatic pressure measurements have been made previously only on n-type $Hg_{1-x}Cd_xTe$[15] and HgTe[16,17] at 300 and 77 °K, and on p-n junctions in $Hg_{1-x}Cd_xTe$.[18] The values obtained for the pressure coefficient of the energy gap vary from 8 to 14×10^{-6} eV/bar.

In this paper we describe first the experimental procedure, then the results obtained, and finally the analysis and interpretation of the results.

EXPERIMENTAL PROCEDURE

Sample Preparation

Single crystals of $Hg_{1-x}Cd_xTe$ were grown by a