Piezoresistance in n-Type InP†

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(Received July 23, 1959)

Piezoresistance measurements were made on n-type InP at 77°K and 300°K. The results suggest a spherical energy band for this material.

I. INTRODUCTION

THE band structure of n-type InP has recently been investigated by galvanomagnetic, optical and thermoelectric power measurements by Glicksman[1] and Newman.[2] These measurements point towards a complex band structure in this material. It seems to possess an isotropic small effective mass $m^*=0.07m_e$ at low carrier densities and an anisotropic large effective mass $m^*\approx0.2m_e$ at higher carrier concentrations.[2] The magnetoresistance measurements by Glicksman[1] indicata a small anisotropy of (100) type for crystals with $n>10^{16}$/cm³. We have made piezoresistance measurements to further investigate the band structure of this material.

II. MEASUREMENTS AND RESULTS

A single crystal of n-type InP was obtained from Siemens Schuckertwerke, Germany. The electron concentration calculated from Hall measurements at room temperature was 2.5×10^{16}/cm³. The resistivity at room temperature was 0.08 ohm-cm. A sample was cut with its long dimensions along the [110] direction. The error in orientation was $\pm1°$. The dimensions of the sample were about 1 mm$\times$2 mm$\times$12 mm. The sample was etched in concentrated hydrochloric acid after lapping. Electrical contacts to the sample were made with an ultrasonic soldering iron using tin as a solder.

The resistance of this sample was measured as a function of hydrostatic pressure at 300°K. The maximum pressure used was 7×10^9 dynes/cm². The resistance increased linearly with pressure throughout the range of applied pressure. The relative change of resistance per unit pressure was found to be:

$$-\frac{1}{P}\frac{\delta R}{R}=(\pi_{11}+2\pi_{12})=-(8.2\pm0.3)\times10^{-12} \text{ cm}^2/\text{dyne},$$

where the π's are the components of the piezoresistance tensor and the sign convention for the π's is the same as that used by Smith.[3]

Longitudinal piezoresistance measurements (with current and stress along [110] direction) were made on the same sample at 77°K and 300°K. The apparatus used for these measurements was similar to that used by Pollak.[4] The stresses applied were of the order of 5×10^7 dynes/cm². The measurements gave the following results:

$$\frac{1}{X}\frac{\delta R}{R}=\frac{1}{2}(\pi_{11}+\pi_{12}+\pi_{44})$$
$$=-(1.3\pm0.5)\times10^{-12} \text{ cm}^2/\text{dyne},$$

where X is applied stress. The values of $(\delta R/XR)$ at 77°K and 300°K were the same within the experimental error.

No corrections due to dimensional changes of the sample were made for either measurement, as these corrections are estimated to be small ($\approx2\times10^{-12}$ cm²/dyne) and do not affect our final conclusions.

III. DISCUSSION

Because of lack of more material, we could not make the third measurement necessary to evaluate the two shear coefficients ($\pi_{11}-\pi_{12}$) and π_{44}. However, from the above data we find that $(\pi_{11}-\pi_{12})+3\pi_{44}=8.6\times10^{-12}$ cm²/dyne. This result excludes the possibility of one of the shear coefficients being large ($\approx100\times10^{-12}$ cm²/dyne) and the other coefficient small ($<10\times10^{-12}$ cm²/dyne), as is the case for n-type germanium and silicon[3] in which the band minima are along [111] and [100] directions, respectively. Thus the band minima for this material do not seem to be along [111] or [100] directions. It is also very improbable that both the shear coefficients are large in such a way as to give a small value for the above combination of the coefficients.

IV. CONCLUSIONS

The shear coefficients seem to be small for this material. This is indicative of a spherical energy band for this material. This result is consistent with Glicksman's results for low carrier concentration material. We are unable to conclude anything from our data about the existence of another higher band, as reported by Glicksman.[1]

ACKNOWLEDGMENTS

† This work is part of a thesis submitted to the Department of Physics, University of Pittsburgh, Pittsburgh, Pennsylvania, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.
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