Piezoresistance Constants of *n*-Type InAs

A. J. TUZZOLINO
Chicago Midway Laboratories, The University of Chicago, Chicago, Illinois
(Received June 5, 1958)

A measurement of the piezoresistance constants of *n*-type InAs as a function of temperature from 77°K to 300°K has been made. From the small magnitude found for the three constants throughout the temperature range investigated, it is concluded that the results of this experiment are consistent with a spherical conduction-band model for InAs.

A MEASUREMENT of the piezoresistance constants of single-crystal specimens of *n* type InAs as a function of temperature from 77°K to 300°K has been made. The experimental arrangement is identical with that described earlier.[1,2] The conventional notation and terminology are used below in reporting the data [1–3]

Single-crystal specimens were cut from large grains of a zone-refined polycrystalline ingot of InAs. The samples were oriented by Laue back-reflection x-ray pictures. The error in orientation was about 2°. A Hall measurement at 77°K gave an electron concentration of 1.1×10^{17} cm^{-3}. The resistivity of the samples was 2.4×10^{-3} ohm-cm at 77°K. The samples were extrinsic throughout the temperature range investigated. The piezoresistance constants Π_{11}, Π_{12}, and Π_{44} were determined by performing "longitudinal"[1–3] measurements on samples oriented along the [110] or [111] directions and a "transverse"[1–3] measurement with current and stress in the [100] and [011] directions, respectively. The tensile stress used was approximately 2×10^{7} dynes cm^{-2}. Since the resistivity of the samples was very low, the stress-induced change in the resistivity was also very small, corresponding to voltage changes in the range 0.2 to 1 microvolt. Consequently, the errors in the Π constants are relatively large (See Table I). Fortunately, the relative order of magnitude for the constants is all that is needed for the discussion below. Table I presents the piezoresistance constants at 300°K and 77°K. The values in Table I have not been corrected for dimensional changes[3] since the elastic constants of InAs are not available. By comparison with InSb,[1,2] it is estimated that dimensional effects will introduce an additional error of the order of $\pm2\times10^{-12}$ cm^2 dyne^{-1} into the quantities reported in Table I. It is evident that the piezoresistance effect is small and that the shear constants[1–3] $\Pi_{11}-\Pi_{12}$ and Π_{44} are very nearly zero.

Recent theoretical[4,5] and experimental[6,7] studies of the conduction band of zinc-blende type crystals indicate that the conduction band of InAs, in particular, is isotropic, i.e., the constant-energy surfaces for the electrons are spheres. The theory of the piezoresistance effect for such a band structure[8,9] predicts a zero, or very small, magnitude for the shear constants over the complete temperature range. The small values found for the shear constants suggest such a band structure. Recently, this prediction has been verified experimentally for the compound InSb.[2] For example, in the extrinsic temperature range the shear constants for *n*-type InSb, which is known to have spherical energy surfaces for electrons,[5,10] are independent of temperature and are approximately two orders of magnitude smaller than for *p*-type InSb,[1,2] which is expected to have "large"[5,8,9] temperature-dependent values for the shear constants. The magnitudes of the Π constants found for the extrinsic *n*-type InAs reported here are smaller than, but of the same order as, those found for extrinsic *n*-type InSb.[2] In addition, no temperature dependence was found for the Π constants for InAs from 77°K to 300°K, within experimental error. Therefore, by comparing the magnitude of the Π constants in the extrinsic range with theoretical predictions and the corresponding magnitudes for InSb, it is concluded that the results of this experiment are consistent with a spherical conduction-band model for InAs.

TABLE I. Piezoresistance constants of *n*-type InAs at 300°K and 77°K.

	300°K	77°K
Π_{11}(cm^2 dyne^{-1})	$(-5\pm3)\times10^{-12}$	$(-3\pm3)\times10^{-12}$
Π_{12}(cm^2 dyne^{-1})	$(-5\pm3)\times10^{-12}$	$(-8\pm3)\times10^{-12}$
Π_{44}(cm^2 dyne^{-1})	$(0\pm3)\times10^{-12}$	$(-1\pm3)\times10^{-12}$

ACKNOWLEDGMENT

I would like to thank R. Harada for the ingot of InAs.

[1] A. J. Tuzzolino, Phys. Rev. **109**, 1980 (1958).
[2] R. F. Potter, Phys. Rev. **108**, 652 (1957).
[3] C. S. Smith, Phys. Rev. **94**, 42 (1954).
[4] G. Dresselhaus, Phys. Rev. **100**, 580 (1955).
[5] E. O. Kane, J. Phys. Chem. Solids **1**, 249 (1956).
[6] R. J. Sladek, Westinghouse Research Laboratory Scientific Paper 8-1038-P6, 1956 (unpublished).
[7] F. Stern and R. M. Talley, Phys. Rev. **100**, 1638 (1955).
[8] C. Herring, Bell System Tech. J. **34**, 237 (1955).
[9] E. N. Adams, Chicago Midway Laboratories Technical Report, CML-TN-P8, 1954 (unpublished).
[10] Dresselhaus, Kip, Kittel, and Wagner, Phys. Rev. **98**, 556 (1955).