V. THERMOELECTRIC PROCESSES AND MATERIALS*

Prof. R. B. Adler
R. E. Nelson
Jane H. Dennis
O. P. Manley
Prof. P. Aigrain†‡
L. Godefroy‡
J. Tavernier‡

A. ANISOTROPIC THERMOELECTRIC EFFECTS IN BISMUTH TELLURIDE

1. Theory

In Quarterly Progress Report No. 55 (pages 48-49), an analysis was made of anisotropic thermoelectric power produced in nondegenerate semiconductors by two simultaneously competing scattering mechanisms that act upon a single type of charge carrier.

Since the writing of that report, the possibility that anisotropy may arise in two-carrier systems, from mixed conduction in bands that differ in their detailed structure, has been studied carefully. The 2:1 anisotropy in bismuth was computed from the theory, with results that are in agreement with accepted experimental values, and are substantially identical to those published recently by Chandrasekhar (1).

2. Experiment

Apparatus was developed to measure thermoelectric power at room temperature in samples of Bi_2Te_3 oriented parallel and perpendicular to the cleavage planes. Precision of approximately 1μv/°C, which is better than 1 per cent for most samples, has been achieved.

By using iodine-doped material prepared in a Bridgman furnace, it was possible to prepare a melt from which quite uniform n-type single crystals may be drawn in a crystal putter.

Preliminary measurements of thermoelectric power at room temperature, made on the crystals described above, show thermoelectric powers parallel to the cleavage planes ranging from 118 to 125μv/°C in different samples, and from 89 to 104μv/°C perpendicular to the cleavage planes in the same samples. These results are reconcilable with Goldsmid's report of a 25μv/°C difference between the thermoelectric powers in the two directions for a more heavily doped zone-refined single crystal with mean thermoelectric power of 220μv/°C.

The temperature dependence of thermoelectric power and resistivity will be

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†Part-time visiting professor in the Department of Electrical Engineering, M. I. T.

‡Laboratoire Central des Industries Électriques, Fontenay-aux-Roses, France.

investigated along both directions in the crystals, in order to distinguish between the two sources of anisotropic thermoelectric power which are being considered.

Jane H. Dennis

References

1. S. Chandrasekhar, J. Phys. Chem. Solids 11, 268 (1959).

B. MERCURY TELLURIDE EVALUATION

The determination of the temperature dependence of thermoelectric power in mercury telluride is now in progress. The sample holder and heaters required for the measurement have been designed to minimize differences between the temperatures at the ends of the sample and at the thermocouples employed to measure these temperatures.

Preliminary results show an n-type thermoelectric power of 130μv/°C at room temperature, which decreases approximately linearly in magnitude as a function of inverse temperature. The zero value occurs at approximately 200°K.

R. E. Nelson

C. TRANSPORT OF CONTACT MATERIALS IN BISMUTH TELLURIDE

This study was carried out by Oscar P. Manley. The results, submitted to the Department of Electrical Engineering, M. I. T., May 1960, as a thesis in partial fulfillment of the requirements for the degree of Doctor of Science, will also appear in a summary technical report of our project.

R. B. Adler

D. THERMAL CONDUCTIVITY STUDIES*

1. Theory

An account of the theory of thermal conductivity at temperatures above the Debye temperature, upon which we have been reporting, is now available in a report entitled "Contribution à l'Étude de la Conductivité Thermique de Réseau dans les Solides," by

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*This work is being performed at Laboratoire Central des Industries Électriques, Fontenay-aux-Roses, France.

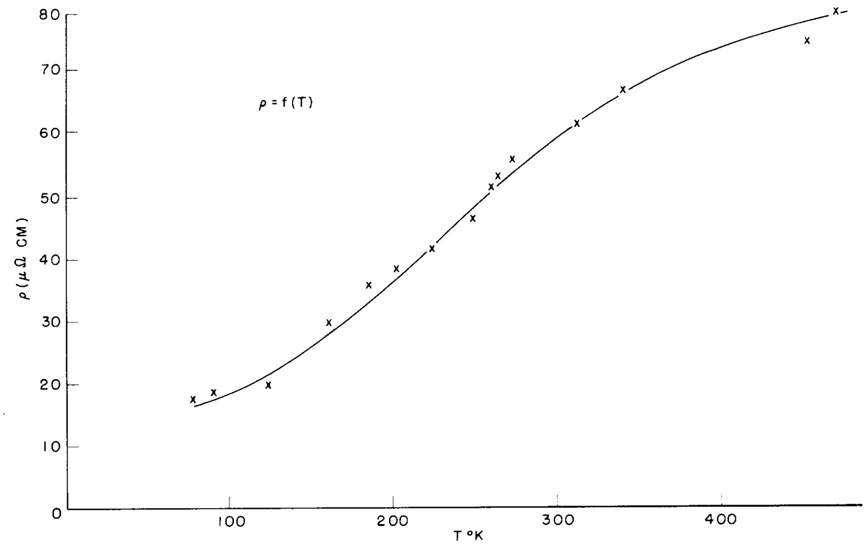

Fig. V-1. Resistivity of Cd_3As_2.

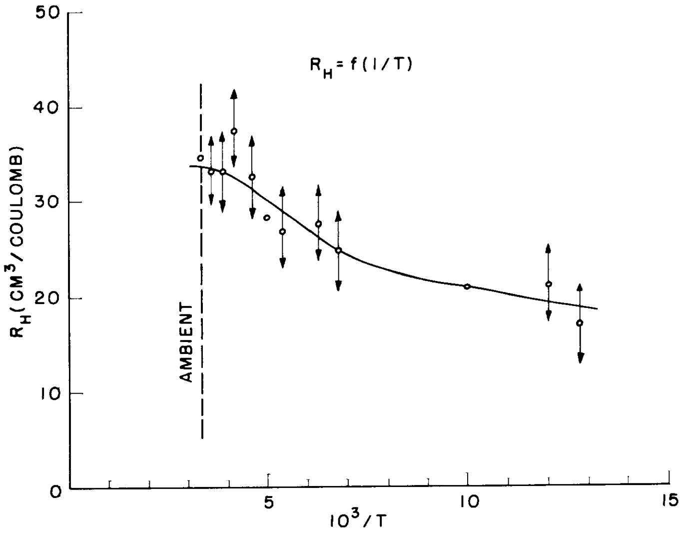

Fig. V-2. Hall effect for Cd_3As_2.

J. Tavernier, May 15, 1960. [A few copies are on file in the Document Room of the Research Laboratory of Electronics. Copies are available for distribution, upon request from Laboratoire Central des Industries Électriques.]

2. Measurement of Thermal Conductivity

The heat-wave method of determining thermal conductivity, outlined in previous quarterly progress reports, is discussed at length in a report entitled "Mesure des Conductivités Thermiques en Régime Variable," by J. C. Perron, May 15, 1960. [Copies may be obtained as indicated above.]

3. Preparation and Properties of Cd_3As_2

An investigation of the compound Cd_3As_2 has been initiated. This material seems especially promising from the thermoelectric standpoint because its electric conductivity is high, whereas its thermal conductivity is expected to be rather low. The crystal structure of this compound, determined by Passerini, is, except for cadmium vacancies, similar to that of Mg_2Sn. The electrical and thermal properties of Cd_3As_2 are probably related to this special crystallographic arrangement.

The compound has been prepared by cofusion of the elements in a sealed tube, with a slight excess of cadmium to prevent the formation of $CdAs_2$. Rhombohedral rods and thin platelets, metallic in appearance, presumably Cd_3As_2, accumulated on the walls of the tube. These small crystals, properly crushed, were used to obtain back-reflection powder patterns that confirmed Passerini's results.

Electrical measurements (resistivity (ρ), Hall effect (R), and thermoelectric power (Q)) have been made on polycrystalline samples obtained by re-melting the crystallites mentioned above in vacuum, at approximately 700°C.

Nickel was electroplated on the electrode areas, and conventional tin soldering was used to fix the electrodes on the nickel-plated areas.

Table V-1. Properties of Cd_3As_2.

	T = 80°K	T = 273°K
ρ(ohm-cm)	18×10^{-6}	62×10^{-6}
R(cm^3/coulomb)	0.16	0.33
$N = 1/Re(cm^{-3})$	4×10^{19}	2×10^{19}
$\mu = R/\rho(cm^2/v\text{-}sec)$	8,900	5,300
Q(μV/degree)	-	50

The results obtained with one of the most recent samples prepared are shown in Table V-1 and plotted in Fig. V-1 (ρ versus T), and Fig. V-2 (R versus 1/T).

The carrier concentrations N and mobilities μ in Table V-1 were calculated under the assumption that only one type of carrier is present.

It should be noted that the carriers appear to be electrons from the sign of the thermoelectric power, whereas the Hall effect would indicate a p-type material. This anomaly, together with the anomaly concerning the carrier concentration, is now being investigated. At least, the high mobility that has been reported by others has been confirmed.

Much more work is needed to understand the electrical properties of this especially interesting compound.

J. Tavernier, P. Aigrain