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Abstract

Full Text

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CHANGE IN THE ELECTRICAL RESISTANCE OF PbTe, CdTe, Bi_2Te_3 AT PRESSURES UP TO 200,000 kg/cm^2

In the present work the authors measured the electrical resistance of PbTe, CdTe, and Bi_2Te_3* under pressure, continuing the work whose results were published earlier [(1)]. All measurements were carried out at room temperature.

Figure 1 shows the change in the electrical resistance of three samples of lead telluride as a function of pressure. The investigated samples had hole conductivity and differed from one another in degree of purity and in electrical properties (see Table 1), where σ is the conductivity, α is the thermoelectric-power coefficient, and n is the carrier concentration.

Table 1

Sample No.	σ, $\Omega^{-1} \cdot cm^{-1}$	α, μV/deg	$n \cdot 10^{-19}$, cm^{-3}
1	2910	68	4.9
2	590	205	0.62
3	772	195	0.624

As is seen from Fig. 1, curves 1, 2, and 3 differ somewhat from one another, which is explained by differences in the electrical properties and geometrical dimensions of the initial samples. However, the minima and maxima of the curves correspond to identical pressure values—the curves have minima at a pressure of 65,000 kg/cm^2 and maxima at 80,000-85,000 kg/cm^2.

PbTe at atmospheric pressure has a cubic structure of the NaCl type. Apparently, at a pressure of 75,000-80,000 kg/cm^2 and room temperature a polymorphic transformation of lead telluride occurs.

Figure 2 shows the change in the electrical resistance of n-type cadmium telluride at pressures up to 200,000 kg/cm^2. At atmospheric pressure it has a high electrical resistivity; at a pressure of about 50,000 kg/cm^2 the electrical resistivity decreases abruptly; as the pressure is increased from 50,000 to 200,000 kg/cm^2 the electrical resistivity decreases by about 4 times, and CdTe becomes a good conductor with a specific electrical resistivity of the order of 10^{-4}–10^{-5} $\Omega \cdot cm$.

Fig. 1. Change in the electrical resistance of PbTe of different degrees of purity at pressures up to 200,000 kg/cm^2. 1, 2, 3–samples according to Table 1.

Figure 1: Fig. 1. Change in the electrical resistance of PbTe of different degrees of purity at pressures up to 200,000 kg/cm^2. 1, 2, 3–samples according to Table 1.

Fig. 2. Change in the electrical resistance of CdTe at pressures up to 200,000 kg/cm^2

Figure 2: Fig. 2. Change in the electrical resistance of CdTe at pressures up to 200,000 kg/cm^2

At atmospheric pressure CdTe has the sphalerite-type structure. Apparently, at a pressure of about 50,000 kg/cm^2 and room temperature a polymorphic transformation of CdTe occurs. It should be noted that a jump-like decrease in electrical resistivity under pressure has also been observed by other investigators.

Fig. 1. Change in the electrical resistance of PbTe of different degrees of purity at pressures up to 200,000 kg/cm^2. 1, 2, 3–samples according to Table 1.

* In the present work, the resistance measurements of Bi_2Te_3 were carried out later than in the work of E. S. Itskevich, S. V. Popova, and E. Ya. Atabaeva.

investigators [2]. The curve of the dependence of electrical resistance on pressure obtained by them (see Fig. 3) has approximately the same character as in Fig. 2. However, in the absolute value of the step-like decrease in resistance and in the value of the pressure at which it occurs, it differs substantially from the curve in Fig. 2.

The difference in the magnitude of the jump in electrical resistance can be explained by the different degree of purity of the starting materials and by the method of producing the pressure (which may be reflected, for example, in the degree of hydrostaticity of the pressure): in the experiments of the authors mentioned, the specimen was made in the form of a thin film, whereas in our work the pressure was produced in a volume of ~ 0.5 cm^3.

Fig. 2. Change in the electrical resistance of CdTe at pressures up to 200 000 kg/cm^2.

The difference in the value of the pressure of the jump in electrical resistance is difficult to explain, especially since in work [2] the pressure was determined not on the Bridgman scale (as in our work), but on the Kennedy and LaMori scale [3], which gives lower pressure values for reference points obtained from the jump in electrical resistance of the known metals Bi, Fe, Pb, Ba. Thus, for example, the transition Bi_{VI}—Bi_{VII} occurs on the Kennedy and LaMori scale at 91 000—94 000 kg/cm^2, and on the Bridgman scale at $\sim$ 125 000 kg/cm^2. The approximate values of the specific electrical resistance of CdTe after the jump

Fig. 3. Curve of the dependence of electrical resistance on pressure for CdTe at pressures up to 300 kbar

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Fig. 4. Change in the electrical resistance of Bi_2Te_3 at pressures up to 200,000 kg/cm^2

Figure 4: Fig. 4. Change in the electrical resistance of Bi_2Te_3 at pressures up to 200,000 kg/cm^2

coincide in order of magnitude in both works.

Fig. 3. Curve of the dependence of electrical resistance on pressure for CdTe at pressures up to 300 kbar.

Fig. 4. Change in the electrical resistance of Bi_2Te_3 at pressures up to 200 000 kg/cm^2.

Figure 4 shows the dependence of the electrical resistance of p-type Bi_2Te_3 on pressure, where R_{30} is the electrical resistance of Bi_2Te_3 at $P = 25\,600$ kg/cm^2 (reference point Bi_I—Bi_{II}). The value of the electrical

the resistance R_{30} is taken as the initial value, since at lower pressures the electrical resistance of the specimen changes owing to changes in its geometrical dimensions, caused by the flow of the pressure-transmitting substance out of the working volume of the chamber.

It is known [4] that in bismuth telluride under pressure the width of the forbidden band decreases from 0.171 eV at atmospheric pressure to 0.104 eV at 30 000 kg/cm^2. The electrical resistance at room temperature decreases over this pressure interval by a factor of 4. With a further increase in pressure, as can be seen from Fig. 3, the electrical resistance also decreases (in the pressure range from 30 000 to 200 000 kg/cm^2, by ~ 30 times). In the region of 100 000 kg/cm^2 a certain change in the course of the curve is observed, which is possibly caused by a polymorphic transformation of Bi_2Te_3. At atmospheric pressure bismuth telluride has a rhombohedral structure.

In conclusion it should be noted that the observed polymorphic transformations in the semiconductors studied are reversible. When the pressure is reduced to atmospheric, the electrical resistance of the specimens studied assumes its initial value, apart from a slight decrease caused by changes in geometrical dimensions during the experiment. No formation of a new phase was detected by X-ray structural analysis. In further studies the temperature dependence of the electrical resistance of these semiconductors on pressure will be determined.

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REFERENCES

[1] L. F. Vereshchagin, A. A. Semerchan, S. V. Popova, N. N. Kuzin, DAN, **145**, No. 4 (1962).
[2] G. A. Samara, H. G. Drickamer, *The Physics and Chemistry of Solids*, **23**, No. 5, 457 (1962).
[3] *Proc. Intern. Conf. Held at Bolton Landing, N. Y., June 13–14, 1960*, p. 304.
[4] Che-Yu Li, A. L. Ruoff, C. W. Spencer, *J. Appl. Phys.*, **32**, 1733 (1961).

Note: Figure translations are in progress. See original paper for figures.