PHYSICS

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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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CHANGE IN THE ELECTRICAL RESISTANCE OF PbS, PbSe, AND PbTe UNDER PRESSURE UP TO 200,000 kg/cm^2

It is of interest to study the change in the electrical resistance of lead sulfide, lead selenide, and lead telluride under pressure up to 200,000 kg/cm^2. As is known, PbS, PbSe, and PbTe are close in their physical and chemical properties, since sulfur, selenium, and tellurium are chemical analogues. These substances have a NaCl-type crystal structure with lattice constants equal, respectively, to 5.91, 6.14, and 6.34 Å.

Figures 1, 2, and 3 present the change in the electrical resistance of PbS, PbSe, and PbTe (1) under pressure up to 200,000 kg/cm^2. As is evident from the figures, the curves have the same form. At first, with increasing pressure, the electrical resistance of the substance decreases, passes through a minimum, then rises sharply, passes through a maximum, and decreases smoothly. Several samples of each substance of different degrees of purity were investigated and, consequently, with different initial electrical properties. As is evident from the figures, the corresponding curves do not coincide with one another and differ in the values of R_{min} and R_{max}, as well as in their ratio (R_{min} and R_{max} are the minimum and maximum resistances of one and the same sample in the interval from atmospheric pressure to 200,000 kg/cm^2). This difference may be so large that, for different samples of one and the same substance (for example, PbSe), different coordinate axes have to be constructed (see Fig. 2). The samples differ very little in their geometric dimensions (2).

Fig. 1. Change in the electrical resistance of PbS under pressures up to 200 kbar.
1 $-n$-type, $n = 4.9 \cdot 10^{18}$;
2 $-p$-type, $n = 1.5 \cdot 10^{18}$ cm^{-3}.

Table 1

Figure 2

Figure 2: Figure 2

Substance	P^*_{min}	P^*_{max}	a, Å
PbS	25,000	50,000	5.91
PbSe	40,000–45,000	75,000–80,000	6.14
PbTe	65,000	80,000–85,000	6.34

* On the Bridgman scale.

A complete study of the electrical properties for each of these substances under pressure as a function of the type of conductivity, the number and kind of impurity atoms, the methods of introducing them into the crystal lattice, etc., is of great independent interest.

However, in the present work we must note that, despite the difference in the degree of purity of the initial substances, the values of P_{min} and P_{max} for each substance remain strictly constant and are different for PbS, PbSe, and PbTe (P_{min} and P_{max} are the pressure values at which the resistance of one and the same sample is, respectively, minimal and maximal in the interval from atmospheric pressure to 200,000 kg/cm^2).

As can be seen from Table 1, the values of P_{min} and P_{max} increase with increasing lattice constant a and agree well, for PbS and PbTe, with the available literature data (^{3}). Apparently, PbS, PbSe, and PbTe undergo

Fig. 2. Change in the electrical resistance of PbSe at pressures up to 200 kbar. 1—p-type, $n = 8.3 \cdot 10^{17}$, 2—n-type, $n = 3.3 \cdot 10^{17}$, 3—n-type, $n = 3 \cdot 10^{19}$, 4—p-type, $n = 8 \cdot 10^{19}$ cm^{-3}.

polymorphic transformations in the pressure range studied. The only unusual feature is the transformation range, which reaches several tens of thousands of atmospheres.

It is of interest to compare the data of our work with Bridgman' s data on the compressibility of these compounds at pressures up to 100 000 kg/cm^2 (^{4}). As can be seen from Table 2, the compressibility of PbS, PbSe, and PbTe increases with increasing lattice constants of these compounds at atmospheric pressure. In PbS, at pressures of about 25 000 kg/cm^2, a step-like decrease in volume is observed (not given in Table 2). In PbSe, at a pressure of 43 000 kg/cm^2, the jump in volume is 0.024; in PbTe, at 42 000 kg/cm^2, it is 0.033. In all likelihood, the step-like decrease in the volumes of PbS, PbSe, and PbTe is directly related to the form of the curves obtained in the present work.

Fig. 3. Change in the electrical resistance of PbTe at pressures up to 200 kbar. 1—p-type, $n = 4.9 \cdot 10^{9}$, 2—p-type, $n = 6.2 \cdot 10^{18}$, 3—p-type, $n = 6.24 \cdot 10^{18}$ cm^{-3}.

Figure 3

Figure 3: Figure 3

The observed polymorphic transformations are reversible. When the pressure is reduced to atmospheric pressure, the electrical resistance of the investigated specimens assumes its initial value, except for a slight decrease caused by some change in the geometrical dimensions of the specimens during the experiment. By the method of X-ray structural analysis in the specimen after

Table 2

Volume of the compounds PbS, PbSe, PbTe in the pressure interval from atmospheric pressure to 100,000 kg/cm^2

Pressure, kg/cm^2	PbS	PbSe	PbTe	Pressure, kg/cm^2	PbS	PbSe	PbTe	Pressure, kg/cm^2	PbS	PbSe	PbTe
1	1.000	1.000	1.000	40,000	0.918	0.922	0.930	70,000	0.892	0.867	0.855
25,000	0.933	0.938	0.944	50,000	0.909	0.888*	0.884**	80,000	0.886	0.858	0.842
30,000	0.928	0.932	0.939	60,000	0.900	0.877	0.869	90,000	0.881	0.849	0.831
								100,000	0.876	0.841	0.820

* Transition at 45,000 kg/cm^2, volume change from 0.917 to 0.893.
** Transition at 45,000 kg/cm^2, volume change from 0.925 to 0.892.

After reducing the pressure to atmospheric, no appearance of a new phase was detected. All measurements were carried out at room temperature.

Of undoubted interest is the study of the temperature dependence of the electrical resistance of these semiconductors under pressure, which will be carried out subsequently.

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