Corresponding Member of the Academy of Sciences of the USSR L. F. Vereshchagin, A. A. Semerchan, N. N. Kuzin, and S. V. Popova

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Abstract

Full Text

PHYSICS

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CHANGE IN THE ELECTRICAL RESISTANCE OF SOME METALS UP TO A PRESSURE OF 250,000 kg/cm^2

The present work is a continuation of the previously published work ([1]) by the same authors on the investigation of changes in the electrical resistance of metals at pressures exceeding 100,000 kg/cm^2.

The aim of the present work is to find new polymorphic transformations in metals accompanied by an abrupt change in electrical resistance at very high pressures. As a result of Bridgman' s investigations ([2]), carried out on various metals and alloys up to a pressure of 100,000 kg/cm^2, and Bondy' s work ([3]) on the phase diagram of bismuth up to a pressure of 130,000 kg/cm^2, a considerable number of polymorphic transformations in metals were discovered in the indicated pressure range. Measurement of the electrical resistance of metals having jumps in electrical resistance occurring at previously determined pressures is a simple and reliable method for calibrating high-pressure apparatus. At the highest pressures, polymorphic transformations occur in bismuth VI—VII $(125,000\ \text{kg/cm}^2)$ ([3]) and in antimony $(130,000\ \text{kg/cm}^2)$ ([1]), accompanied by an abrupt change in electrical resistance. At higher pressures, polymorphic transformations are not known, and therefore their discovery is of undoubted interest.

Fig. 1. Calibration curve of the high-pressure chamber

The authors of the present article measured electrical resistance in a chamber calibrated by known jumps in the electrical resistance of the following metals: Bi I—II, 25,600 kg/cm^2; Bi II—III, 27,000 kg/cm^2; Tl, 45,000 kg/cm^2; Ba, 80,000 kg/cm^2; Bi VI—VII, 125,000 kg/cm^2; pressures exceeding 125,000 kg/cm^2 were determined by extrapolation (see Fig. 1); it was assumed that the dependence of the pressure inside the chamber on the load remains linear.

The measurements were carried out on metal specimens made in the form of wire with a diameter from 0.6 to 0.8 mm. Silver chloride (volume about 0.1

Fig. 2. Change in electrical resistance R/R_{30}

Figure 2: Fig. 2. Change in electrical resistance R/R_{30}

cm^3) served as the pressure-transmitting medium, providing the necessary hydrostaticity in high-pressure experiments. The measurements were carried out at room temperature.

Figure 2 presents the change in the electrical resistance of rhenium, niobium, and yttrium—metals not investigated by Bridgman. The dependence R/R_{30} on pressure is plotted, where R_{30} corresponds to the value of the resistance at a pressure $P = 30,000$ kg/cm^2; at lower pressures, owing to the outflow of the working substance from the chamber volume, a sharp change in the geometric dimensions of the specimen under study is observed, which leads to a sharp change in electrical resistance. It is seen from the figure that, with increasing pressure, there is a smooth decrease in electrical resistance, larger in the pressure range from 30,000 to 100,000 kg/cm^2 (for Re by 22.5%, for Nb by 12.3%, for Y by 30%) and smaller in the range from 100,000 to 250,000 kg/cm^2 (for Re by 7.8%, for Nb by 5.5%, for Y by 14%).

Bridgman [(2)] found an abrupt drop in the electrical resistance (by 16–17%) in zirconium at pressures above 80 000 kg/cm^2. The material was of high purity; Bridgman did not indicate the presence of impurities. The authors measured the electrical resistance of zirconium up to 250 000 kg/cm^2 (see Fig. 2) and did not find an abrupt change in the electrical resistance. However, starting at 90 000 kg/cm^2, a sharp change begins in the course of the curve, which continues from 100 000 kg/cm^2, after which the rate of change of the electrical resistance again slows down. From 30 000 to 250 000 kg/cm^2, the change in electrical resistance amounts to 21%.

Since Bridgman carried out experiments up to 100 000 kg/cm^2, it is possible that he took the sharp change in the course of the curve for a jump in electrical resistance. This is difficult to verify, since he gives no data on the change in electrical resistance in the pressure interval from 80 000 to 100 000 kg/cm^2. It is possible that the character of the change in electrical resistance is affected by the difference in the degree of purity of the material.

Fig. 2. Change in electrical resistance R/R_{30}

The material in our experiments was iodide zirconium (99.7%) with impurities (in %): Al 0.004, Fe 0.03, Hf 0.04, Ca 0.01, Si 0.006, Mn 0.001, Ti 0.003, Cr 0.002, Ni 0.002, Cd $3.5 \cdot 10^{-5}$, Cu 0.001, N_2 0.005, Pb $4.0 \cdot 10^{-5}$%. It should be noted that Bridgman also did not obtain a jump in electrical resistance in zirconium of another degree of purity.

Figure 2 gives the curves of the dependence of the electrical resistance of lead, tin, and cadmium up to a pressure of 250 000 kg/cm^2. The initial portions of the curves up to 100 000 kg/cm^2 coincide with Bridgman' s data. The comparison was made by a simple calculation of the ratio R_{100}—the resistance at 100 000 kg/cm^2—to R_{30}—the resistance at 30 000 kg/cm^2.

According to Bridgman' s data: Pb $R_{100}/R_{30} = 0.694$, Sn $R_{100}/R_{30} = 0.707$, Cd $R_{100}/R_{30} = 0.795$. According to the data obtained by the authors: Pb $R_{100}/R_{30} = 0.683$, Sn $R_{100}/R_{30} = 0.715$, Cd $R_{100}/R_{30} = 0.808$. Thus, the discrepancy with Bridgman' s data does not exceed 2%.

With a further increase in pressure, the decrease in electrical resistance diminishes and amounts, in the pressure interval from 100 000 to 250 000 kg/cm^2, to 12.9% for Pb, 14.2% for Sn, and 10.7% for Cd.

In the present work, the electrical resistance of Wood' s alloy (Bi 53%, Pb 15%, Sn 20%, Cd 2%) was also measured up to a pressure of 250 000 kg/cm^2. As is seen from the curve, it undergoes no noticeable jumps and, when the pressure is changed from 30 000 to 250 000 kg/cm^2, falls by 29%.

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