Measurement of the electrical conductivity of sulfur under superhigh dynamic pressures

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A series of experiments is proposed to study dielectric-metal transition under conditions of dynamic compression. Conductivity of sulfur was measured in the pressure range from 0.3 to 1.1 Mbar.

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In recent years a number of experiments were dedicated to the investigation of dielectric-metal transitions under superhigh static pressures.[1-5] However, resultant data are qualitative since the actual values of pressure, compression and specific conductance are not determined. This is due to the absence of reference points in the megabar pressure range, and somewhat small working volumes of the experimental setups.[6] Application in this type of investigation of dynamic methods for the compression of matter, in which the pressure and compression may be calculated with good accuracy on the basis of conservation laws from the measurement of kinetic parameters of shock waves, is made difficult by the short duration of the experiment. The presence of parasitic inductances in the electric network does not permit a reliable measurement of the specimen resistance in a very brief period of time.[7]

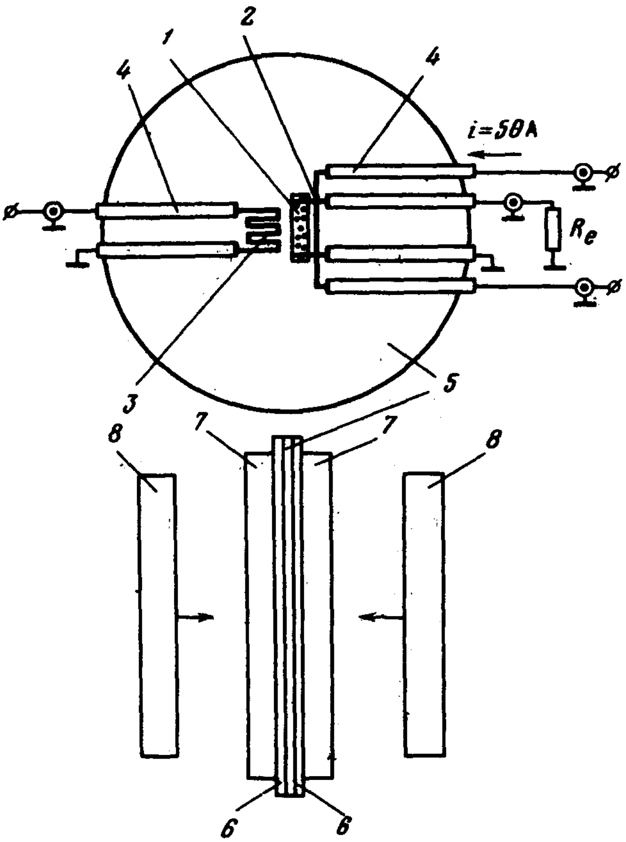

FIG. 1. Experimental setup.

In this report we describe the experimental assembly (Fig. 1) used for the recording of transitions of the dielectric-metal type in a range of dynamic pressures up to 1 Mbar, and we report results of the measurements of conductivity of rhombic sulfur.

The test speciment of semiconductor-purity sulfur (OSCh 16-5) 1 and insulating Teflon washers 5, 6 were clamped together between copper screens 7 with thickness 8 mm and diameter 120 mm. The geometry of the speciment was specified by a rectangular aperture ($0.4\times 4\times 10$ mm^3) in the center washer 5. As a 10-mm thick aluminum striker 8—accelerated by means of an explosive device[8]—is slowed down, a shock wave with a right-angle profile is produced in the screen. The washers and specimen are compressed by colliding shock waves of identical amplitude. Because sulfur and Teflon are less rigid than copper (the series of shock waves distributed between the screens and the plane of impact) loads them to a maximum pressure p_1 that corresponds to the pressure of two head on-colliding waves in copper.

The specimen resistance R_x was measured by an electrical switching method based on four-probe scheme. A shunting resistor 2 made of manganese foil was placed in the immediate vicinity of a specimen. This reduced to a minimum parasitic induc-

TABLE I.

p_1, kbar	340	430	700	1080
R_x, ohm	0,07	0,055	0,05	0,03

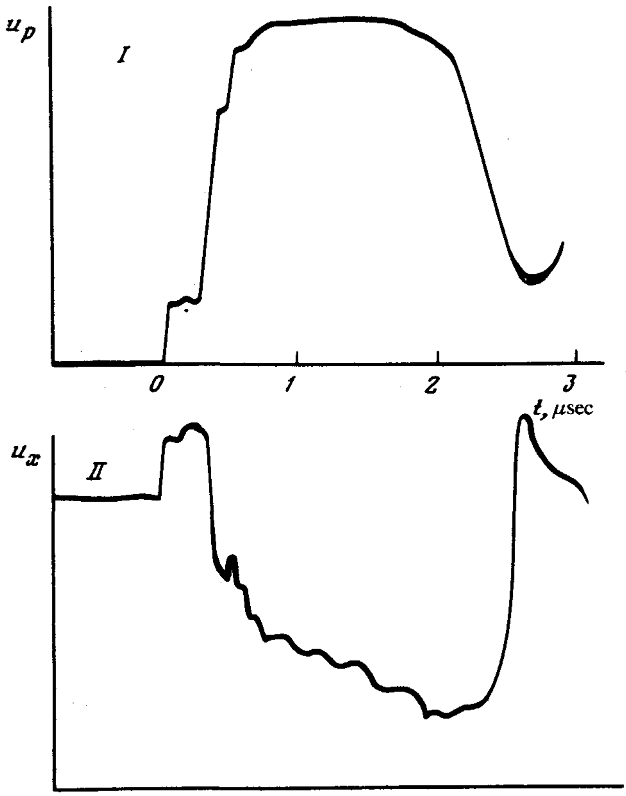

FIG. 2. Experimental oscillogram: $p_1 = 700$ kbar, initial resistance of shunt 0.11 ohm.

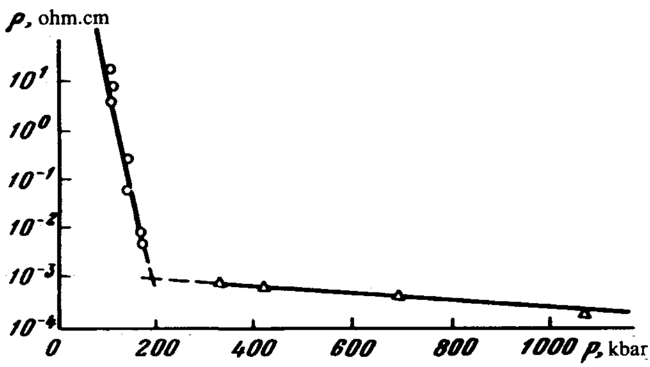

FIG. 3. Dependence of resistivity on pressure: Δ—our data; ○—data from Ref. 10.

tance effects. The length of specimen section across which a voltage drop u_x was measured was 6.5 mm. A manganese pressure pickup 3 whose readings showed changes in the shunt resistance was placed in the same plane with the resistor. Leads 4 consisted of narrow copper foil stips. Recording was made by a two-channel OK-33 oscillograph with input resistance $R_e = 75$ ohm.

One of the experimental oscillograms is shown in Fig. 2. Beam deflection in the first channel u_p is proportional to pressure. Time is measured from the approach of the first shock wave to pickup and the shunting resistor. Values of R_x are shown in Table I.

In the absence of an equation of state for sulfur in the region of high pressures we obtain a value for the compression assuming that sulfur is loaded to a pressure p_1 by a single shock wave. This value is used in calculating the conductivity ρ. In conjunction with this we used the shock adiabat[9] extrapolated to 1 Mbar. Figure 3 shows the corresponding values of ρ. The same figure also shows data obtained at much lower pressures under the conditions of a single compression.[10] A comparison of our data with those from Ref. 10 provides a basis for determining the transition pressure at which sulfur achieves a state characterized by a high electrical conductivity. This is approximately 200 kbar. It is noteworthy to point out that regardless of the intense heating of matter under dynamic loading, this value is in good agreement with the most recent pressure data for the transition of sulfur into a metallic phase under static compression (200–240 kbar).[11]

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