Superconductivity of sulfur at high pressures

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A superconducting transition of a metallic sulfur modification that exists at high pressure has been observed. The superconducting transition temperature is 9.7 K.

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Elements of group VI of the periodic system, which are semiconductors or dielectrics under normal conditions, become metals at high pressures.[1-5] The pressure at which the transition into a metal takes place is 43, 130, and 175–500 kbar for tellurium,[1] selenium,[2] and sulfur.[4,5] The metallic modification of tellurium and selenium become superconducting at low temperatures.[6,7]

The present study was undertaken for the purpose of observing superconductivity of the metallic modification of sulfur. The metallic modification of sulfur was obtained

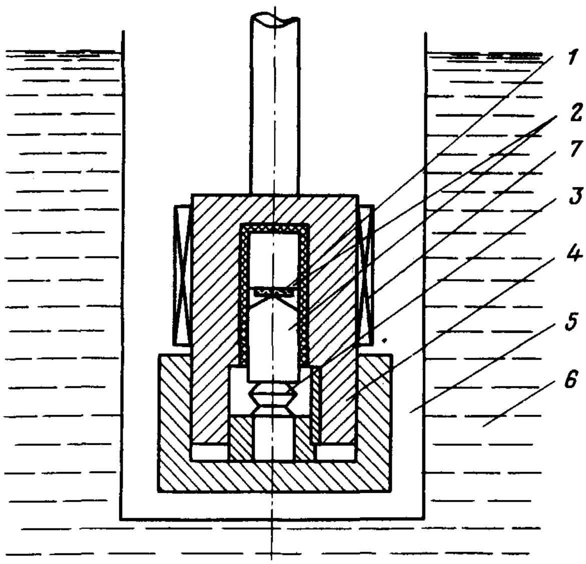

FIG. 1. Setup for the observation of superconductivity at high pressure: 1—sample, 2—plungers, 3—disk springs, 4—screw-type press, 5—helium gas at pressure ~10 Torr, 6—liquid helium, 7—heater.

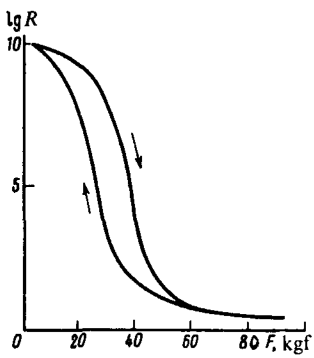

FIG. 2. Dependence of the resistance of the anvils with the sulfur sample on the force.

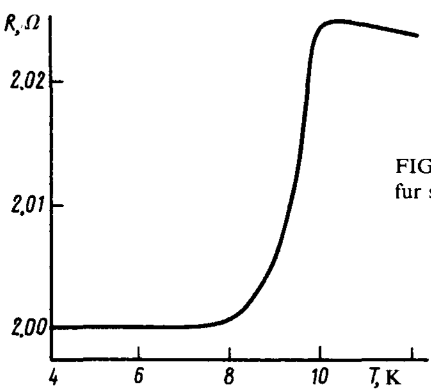

FIG. 3. Dependence of the resistance of the anvils with the sulfur sample on the temperature.

in high-pressure apparatus previously employed to metallize a number of dielectrics[3] and for superconductivity investigations.[8] The high-pressure chamber consists of two plungers made of synthetic diamonds of the Carbonado type. The working surface of one plunger is flat and that of the other is conical with rounded tip.

The pressure between the anvils was produced by a small screw press placed in a cryostat for the low-temperature investigations (see Fig. 1). The resistance of the sample was measured by a potentiometer method. Because of the small dimensions of the sample, the potential electrodes were applied not to the sample but to the metallic mounts of the plungers. Thus, the measured resistance was the sum of the resistances of the sample and of the plungers

$$R = R_{\text{sample}} + R_{\text{plunger}}.$$

Obviously, when the sample goes over into the metallic state, the observed resistasnce R does not vanish. With increasing force applied to the plungers, the resistance decreases smoothly from $R \gtrsim 10^{10}$ to $R \sim 1\text{–}10\ \Omega$ (Fig. 2). The resistance R at large loads was determined mainly by the resistance of the plungers, i.e., $R_{\text{plunger}} > R_{\text{sample}}$.

The metallic state of sulfur, as shown in Ref. 5, is reached at a pressure considerably higher than the pressure at which the sample resistance decreases noticeably.

Figure 3 shows plots of R against temperature. When the temperature increases, the sample goes over from the superconducting to the normal state, and a jumplike change of the resistance R takes place. With increasing current flow through the sample, the superconducting transition temperature decreases.

The superconducting temperature was somewhat different for different samples, different applied forces, and different plungers. This may be due to the dependence of the temperature of the superconducting transition on the pressure. The highest temperature of the superconducting transition in sulfur was 9.8 ± 0.3 K.

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