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Sulfur: A Possible Metallic Form

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SULFUR is normally an excellent insulator. But in spite of its high specific resistance ($>10^{18}$ ohm cm) it appears to be an intrinsic semiconductor,[1] and its position in the periodic system suggests that it might even exist in a metallic state under favorable conditions. There is evidence that its neighbor, phosphorus, undergoes a reversible change into a metallic form at about 40 000 atmos,[2,3] and Bridgman has looked for a corresponding transformation in sulfur at high pressures.[4] He found no sign of a transition below 100 000 atmos.[5]

We have recently subjected sulfur to shock pressures of about 230 000 atmos, and obtained strong indications of metallic conduction under these conditions. The method, illustrated in Fig. 1, was based on an arrangement used previously by Alder and Christian.[3] In the first series of experiments [Fig. 1(a)] the sulfur was in the form of a cast cylindrical pellet with built in electrodes of stainless steel placed at varying distances x from a block of 60/40 RDX/TNT. The electrodes were wired in series with a 1-ohm resistor and a 15-μf paper condenser charged to 135 v. The detonation wave in the explosive closed a pair of trigger electrodes and fed an initiating pulse to a fast oscilloscope. The voltage across the 1-ohm resistor was displayed, a few microseconds later, as a vertical deflection of the oscilloscope trace. A photograph of the trace was then compared with the picture for a true short circuit produced by firing an aluminum disk explosively against a pair of electrodes in a similar circuit. When the separation x was less than 5 mm the two pulses were indistinguishable except for the fact that the sulfur pulse lasted only one microsecond instead of several. Clearly the resistance between the electrodes was well under 1 ohm. When the separation x was 10 mm the sulfur presented a much higher resistance of about 40 ohms, suggesting that the shock had become attenuated in passing up the pellet. The initial shock velocity was 5200 ± 500 m/sec, corresponding to a pressure of about 230 000 atmos in the sulfur. There is no accurate way of estimating the shock temperature, but it was probably in the range 1000 to 1500°K.

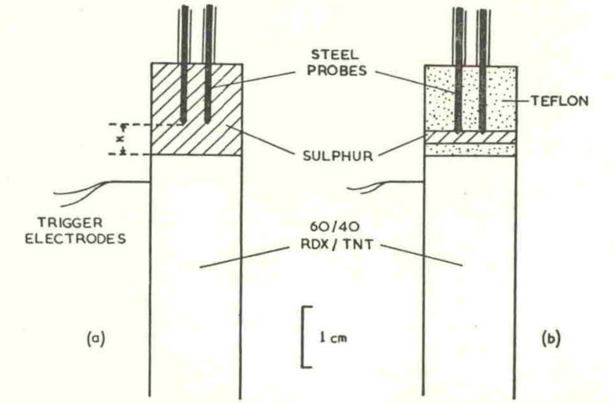

FIG. 1. Arrangements for producing high shock pressures in sulfur. The charges of RDX/TNT were 7 cm long, and were fired at the bottom by a No. 8 detonator.

To set a more definite upper limit to the specific resistance, we used the arrangement shown in Fig. 1(b), where a thin cylindrical rod of sulfur was mounted in a transverse hole drilled through a block of Teflon. In each of a number of experiments the sulfur presented an apparent short circuit in series with 1 ohm. From the dimensions of the specimens, and taking account of the unavoidable inductance in the circuit, we could conclude that the specific resistance was certainly under 0.03 ohm cm. This value is so low that we are inclined to think that the sulfur was metallic and not merely a good semiconductor.

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