Transition of SiO_2 to the conducting state

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The study of the electric conductivity of SiO_2 in the megabar range is stimulated by the needs of geophysics and cosmogony. There are known experiments on dynamic compression of SiO_2 to pressures of several megabars.[1,2] No transition of SiO_2 into the metallic state was observed in these experiments. The absence of metallization of SiO_2 at pressures greatly exceeding the pressure in the earths interior has to some extent "put an end" to the hypothesis (of Ladochnikov and Ramsay) that the earth's core is made of metallic SiO_2.[3–5]

After pressures up to 3 Mbar were reached in Bridgman anvils made of carbonado-type diamonds,[6] after observation of the transition of diamond into the metallic state,[7,8] we have attempted to transform SiO_2 into a metal. We have observed that SiO_2, like diamond compressed between anvils to pressures $P \sim 1$ Mbar, also undergoes a transition to the conducting state.

At the present time we are in the possession of the following facts: 1) the resistance of SiO_2 jumps under pressure from $R \sim 10^8 - 10^9\ \Omega$ to $R \sim 10^2\ \Omega$ (Fig. 1); 2) as the load is removed from the anvil, the resistance returns to its initial value (Fig. 1); 3) heating of the SiO_2 while in the conducting state, at a load F_b (Fig. 2), leads to an increase of the resistance from $R \sim 10^2\ \Omega$ to $R \sim 10^8 - 10^9\ \Omega$.

The return of the resistance SiO_2 to the initial value (item 2) is evidence either that SiO_2 cannot be decomposed under pressure or that the percentage of decomposition is negligible. The jumplike increase of the resistance when the conducting SiO_2 at a load F_b is heated (item 3) indicates the presence of a metastable conducting state of SiO_2.

Thus, the observed phenomena 1), 2), and 3) more readily confirm the metallization of SiO_2 than the absence of such metallization.

Kawai and Nishiyama[9] recently reported observation of conductivity of SiO_2 under pressure. They used an SiO_2 sample in the form of an octahedron compressed by eight anvils. Two anvils were made of tungsten carbide and served simultaneously as electric leads, while the remaining anvils were made of insulating Al_2O_3. They observed a jumplike decrease of the resistance of SiO_2 under pressure. However, when the pressure was removed, the resistance remained smaller than the initial value by at least a factor 10^3. This points to the presence of irreversible processes that lead to a residual conductivity. These processes may be, as indicated in[9], the decomposition of SiO_2 under high pressure and large shear stresses.[10] The large shear stresses occur when the SiO_2 flows into the gap between the anvils.

Moreover, it was observed by us (a report is being readied for press) that Al_2O_3 also becomes conducting under pressure. Since the anvils were made of Al_2O_3, this fact must be taken into account when experiments with SiO_2 are interpreted.

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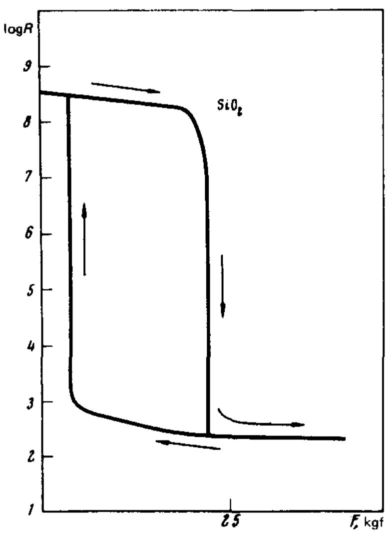

FIG. 1. Dependence of the electric resistance R of a layer of SiO_2 powder on the force F applied to the anvils. Results of one of the experiments.

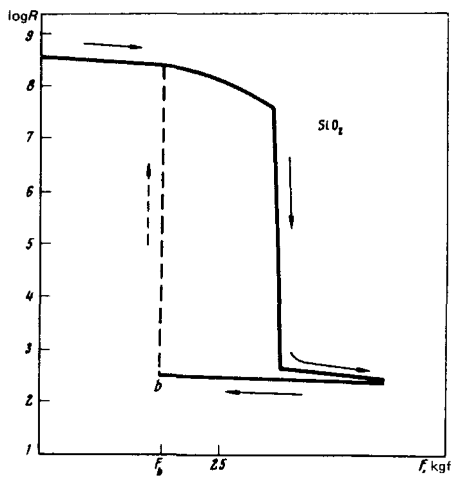

FIG. 2. Plot of $R(F)$. The removal of the load was stopped at a point $F = F_b$ and the sample heated. The variation of the resistance in the course of heating is shown by the dashed line.

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