16. Conductive SiO_2 under High Pressure

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A crystal of SiO_2 with purity of 99.999% has been compressed using a spherical pressure vessel¹⁾ in which electrical resistance of the specimens is made measurable simultaneously.

A sample octahedral in shape with the length of edge 1.5 mm is carefully charged in the pressure chamber and pressurized slowly at the room temperature. A rapid decrease of resistance from 20 to 5 M Ω is first observed as the applied load around the vessel is elevated up to 5.5 ton. The rate of decrease then changes sharply and the pressure-resistance curve has an almost constant slope as shown in Fig. 1. On increasing further the load above 687 ton resistance abruptly drops from 139 k Ω to less than 1 Ω . Taking the shape of the specimens into account we obtain 0.002 $\Omega \text{ cm}^{-1}$ as the specific resistance.

The present vessel is made up of a number of anvils assembled in two stages, one (inner) stage consisting of 8 small cubes and the other (outer) 6 pieces of part of a sphere. The vessel has in and around the central part an octahedral space whose volume is contractible three-dimensionally when loaded by an uniaxial press. Among the eight cubes two are made of tungsten carbide to be used as the electric lead, whereas the remaining ones of sintered alumina, as shown in Fig. 2. If all cubes were conductive it would be questionable that the observed electric conductivity is real. A stray flow via surrounding conductive cubes might have been responsible for the current. Alumina cubes can prevent such electric beak down to occur around the specimen. Further, cardboard spacers are placed sandwiched in the 12 gaps between the neighbouring cubes. The crushable spacers spread out forming gaskets that prevent the sample to extrude from the gaps. The compressed gaskets remain in the position as insulator and give sufficient lateral mechanical support to protect the cubes from rupture.

Next $\text{Fe}_{0.95}\text{O}$ was compressed in the same way as SiO_2 till it becomes conductive too. (Stoichiometric deviation is unavoidable in the crystal synthesized from iron in CO-CO₂ gas mixture at high temperature.) The pressure has been found much lower than that at which SiO_2 was transformed.

Fig. 1. Effect of pressure upon electrical resistance of SiO_2 .
Reversible curve accompanying hysteresis occurred.

A few years ago one of the present authors with Mochizuki succeeded to bring NiO , TiO_2 , Fe_2O_3 and Cr_2O_3 ^{2),3)} into the metallic state in turn under pressure increasing in this order. The respective pressures are all higher than that required for the metallic transition of FeO , but definitely lower than that for the transition of SiO_2 .

Hawke *et al.*⁴⁾ recently shocked an SiO_2 crystal together with magnetic flux and fired explosive powders placed around the specimens. The magnetic flux was used not only to hold the specimens up in the tube but also to evaluate the pressure magnetically. These authors report that SiO_2 remained still to be insulator when the shock pressure exceeded 4 Mb. Al'tshuler⁵⁾ independently shocked the same material up to 2 Mb but did not mention of the metallic state. Shock and static pressures differ from each other in many respects and no good standardization of them is possible at present.

The Mott transition has been emphasized in explaining the be-

Fig. 2. Arrangement of eight cubes of which one is taken away. 1 and 2 were made of tungsten carbide, and the others of Alumina respectively.

havior of conductive oxides (such solid solution series as V_2O_3 – CrO_3 ⁶⁾) under pressure.

Vereshchagin *et al.*⁷⁾ reported that a tendency of reduction in oxides arose and prevailed when they were squeezed between the Bridgman anvils.

Several years ago sulfur was converted into the metallic state by Hamman⁸⁾ who pressed it at 0.23 Mb in his shock tube at about 1000°C. The same state was obtained under the static pressure in a spherical vessel similar to the present one⁹⁾ at the room temperature. Of the group of elements Se, Te, S and O the former three have been rendered metallic under pressures under 0.1 Mb.¹⁰⁾ Oxygen is an only exception. The pressure we produced in making the conductive SiO_2 , however, is far greater than the pressure under which sulfur breaks up. Metallic oxygen might have been formed in our vessel if SiO_2 had been broken up into its constituent elements before the Mott transition (or possible reduction) took place. The split of oxides into two metals may be considered possible, too.

On the other hand our experiment may throw light upon the problem since Bernal¹¹⁾ and Ramsey¹²⁾ regarding the formation of the earth and other planets with a layered structure having the core, mantle and atmosphere.

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