Electrical Resistance Measurement for Metallic Oxygen

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We have performed the electrical resistance measurement of oxygen using a diamond anvil cell. With increasing pressure, the resistivity of oxygen was found to decrease and reached 0.3 ohm cm at around 95 GPa that was still comparable to that of semiconductor. We present measurements of the temperature dependence of electrical resistance of oxygen up to 115 GPa and down to 45 mK in order to observe the metallic behavior in the temperature dependence.

Introduction

Oxygen molecule, has been studied for both the magnetism and the structure, also interests us of metallization at high pressures. Optical reflection measurement[1] suggested the metallization at 95 GPa and x-ray diffraction study[2] reported a new high pressure phase (ζ) above 96 GPa which is regarded the metal phase of oxygen. We presented[3] the first observation of electrical resistance of oxygen at room temperature up to 95±5 GPa showing a rapid decrease of resistance by the compression. In this paper, we measured the temperature dependence of electrical resistance of oxygen up to 115 GPa and down to 45 mK in order to clarify the insulator-metal transition and the behavior in the temperature dependence.

Experimental

A diamond anvil cell (DAC) made of nonmagnetic Be-Cu alloy is used to generate pressures with a pair of 1/3 carat synthetic diamonds of the top surface diameter of 100 µm and beveled angle of 7 degrees from a culet diameter of 300 µm. The sample chamber of 50 µm-hole is prepared at the center of prepressed Al₂O₃ layer in metal gasket sheet. The arrangement of electrodes and the insulation layer in DAC is shown in Fig. 1. The sample of oxygen with a purity of 99.998% is introduced into the chamber at 77 K in a liquid nitrogen cryostat equipped with a pressure loading mechanism. Resistance is measured by 4-terminal method with ac measuring current of 1 mA. The isolation of those electrodes...
from the metal gasket is confirmed above 200 MΩ with additional electrode on the metal gasket (not shown in the figure) during all experimental processes. The pressure is determined by the ruby R1 line at both room temperature and 77 K. The pressure at low temperatures is found slightly change during cooling but within 5 %. After pressure determination, the cell is directly connected to the mixing camber of a 3He / 4He dilution refrigerator. The temperature is measured on the body of DAC, however, the sample temperature is expected to be close to that of DAC as the sample has negligible small heat capacity and metallic thermal conductivity.

**Results**

Figure 2 shows the relative resistance from the resistance divided by that of 300 K, as a function of temperature at 55, 72, 98 and 115 GPa. At pressures below 98 GPa, the temperature dependence of resistance behaves as that of semiconductor where the slope decreases with increasing pressure. At 98 GPa, the resistance becomes almost temperature independent, however the behavior looks strange which may be caused by a pressure changing during cooling. Finally, the slope of the resistance clearly changes to positive which indicates the metallization of oxygen. This measurement of the temperature dependence reveals the critical pressure is around 98 GPa which is comparable with previous reports.\(^{1,2}\)

The examinations at lower temperatures show tendency of slight increase of the resistivity below 60 K and 20 K at 98 GPa and 115 GPa respectively. This may suggest that the ζ-oxygen at these pressures are not still usual metal. Another striking thing is the observation of a small but abrupt drop at and below temperature of 0.6 K. The drop is possibly attributed to the transition to superconductivity which gives evidence of absence of magnetism, however the confirmation is now going on.

**References**