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Electrical resistance of SrFeO₂ at ultra high pressure

Masayoshi KIKUCHI[§], Tomoko KAGAYAMA¹, Katsuya SHIMIZU¹, Hiroshi KAGEYAMA²

¹KYOKUGEN, Osaka University, Toyonaka, Osaka 560-8531, Japan

²Dept. of Chemistry, Kyoto University, Sakyo, Kyoto 606-8502, Japan

kikuchi@hpr.stec.es.osaka-u.ac.jp

Abstract. SrFeO₂ shows antiferromagnetic and insulating order at ambient pressure. The crystal structure of SrFeO₂ has 2-dimensional FeO₂ plate and is interested in because this is common structure of high temperature superconductor. SrFeO₂ has M-I, magnetic and spin transition with applying pressure. If magnetism disappears and metallization occurs with applying pressure, SrFeO₂ may show superconductivity because of the crystal structure, so we measured electrical resistance at high pressure up to 150 GPa and low temperature down to 100 mK.

1. Introduction

SrFeO₂ is in the group of P4/mmm and shows an antiferromagnetic order at a remarkably high Néel temperature ($T_N=473$ K) [1]. SrFeO₂ is expected to have superconductivity, because the crystal structure is same as that of SrCuO₂, which is known as showing high-temperature superconductivity. SrFeO₂ exhibits a transition from high spin ($S=2$) antiferromagnetic state to intermediate spin ($S=1$) ferromagnetic state at about 32 GPa.

Antiferromagnetism and ferromagnetism is related by super-exchange interaction. At low pressure, that is antiferromagnetic state, Fe²⁺ orbital is $(d_z^2)^2(d_{xz}d_{yz})^2(d_{xy})^1(d_{x^2-y^2})^1$. At high pressure up to 32 GPa, that is ferromagnetic state, Fe²⁺ orbital is $(d_z^2)^2(d_{xz}d_{yz})^3(d_{xy})^1(d_{x^2-y^2})^0$ [2]. The transition is accompanied by a change in the conducting state from insulating to metallic [3].

For further high pressure, another spin transition from $S=1$ to $S=0$ is expected at about 220 GPa by first-principle study [2]. A pressure induced transition to nonmagnetic state was reported by recent ⁵⁷Fe Mössbauer spectroscopy measurement [4].

2. Experimental method

The powder sample of SrFeO₂ was synthesized by the reaction with CaH₂ of a slightly oxygen-deficient perovskite, SrFeO_{2.875}, by Kawakami *et. al* [3]. The high-pressure electrical resistivity measurements were performed up to 150 GPa using a diamond-anvil cell made of CuBe used with type-Ia diamond anvils with tips of 300 μm in diameter. A rhenium was used as a gasket material that was insulated from platinum electrodes by a layer made of compressed mixture of c-BN and epoxy, and pressed it into 30 μm thickness between diamond anvils by using a DAC, on which sample powder and platinum electrodes were placed together. The photograph and scheme of setting is shown in Figure 1. The pressure was determined by means of ruby-fluorescence manometry up to 70 GPa and diamond-Raman manometry above 70 GPa. To estimate the pressure, ruby chips were placed on the powder sample of



SrFeO₂. Electrical resistance was measured with a standard ac four-probe method between 100 mK and 300 K up to 150 GPa. In this electrical resistance measurements, the initial sectional area and the distance between probes were about $38\mu\text{m} \times 5\mu\text{m}$ and $7\mu\text{m}$, respectively.

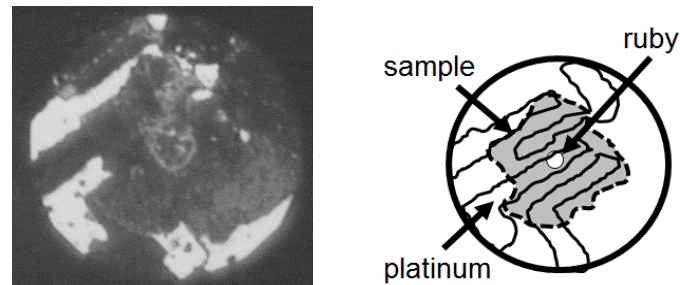


Figure 1. The scheme of the setting of this measurement.

3. Result and discussion

The pressure dependence of electrical resistivity of SrFeO₂ at room temperature up to 150 GPa is shown in Figure 2. In low pressure, electrical resistivity is very high and suddenly decreases. From ambient pressure to 80 GPa, the electrical resistivity decreases by 6 to 7 orders in magnitude. The behaviour is consistent with previous work. At higher pressure, the electrical resistivity gradually decreases and tends to saturate. It is considered to be shown metallic state.

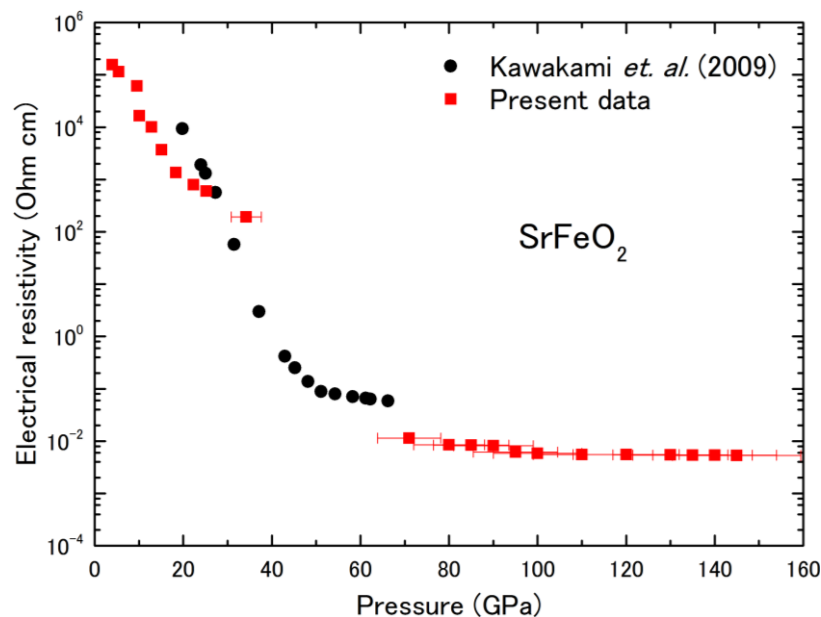


Figure 2. The pressure dependence on electrical resistivity is measured at room temperature up to 150 GPa.

The temperature dependence of electrical resistivity normalized at 280 K is shown in Figure 3. Between 34 GPa and 70 GPa, the slope changes from negative to positive. In this pressure region, M-I transition would be shown. In fact, measurement of ours correspond with that of Kawakami *et al* [3]. Between 70 GPa and 90 GPa, the slope changes from positive to negative. In this pressure region, The M-I transition is believed to occur again. Above 90 GPa, the slope is negative in all temperature region.

But, the temperature dependence on electrical resistivity changes between 90 GPa and 130 GPa. In this research, SrFeO₂ hasn't shown superconductivity although we measured down to 100 mK.

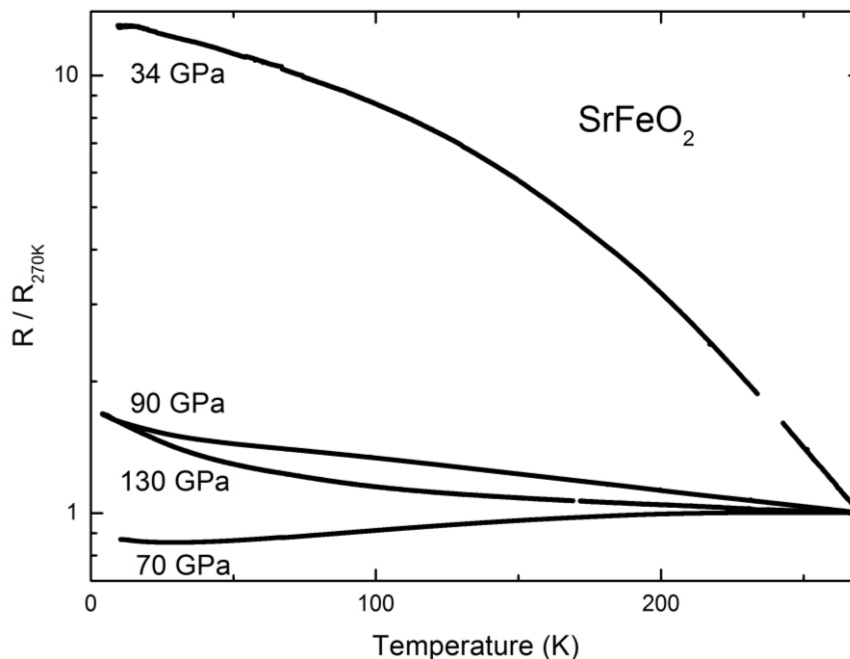


Figure 3. The temperature dependence on electrical resistivity normalized at 280 K from 34 GPa to 130 GPa.

The temperature dependence on electrical resistivity normalized at 280 K from 70 GPa to 90 GPa is shown Figure 4. At 70 GPa, the slope is positive in almost all temperature region but turns negative at low temperature. The tendency become prominent at higher pressure. At 80 GPa, the slope is negative from room temperature to about 100K, and the slope turns to positive from this temperature. The temperature dependence of the electrical resistivity has negative curvature at high temperature and positive at low temperature. The inflection point shown by an arrow in Figure 4 shifts to low temperature with applying pressure. The transition from metal state to insulating state may occur and metal state and insulating state are crossover at 70 GPa to 90 GPa. The reason of slope turns negative at lower temperature is that we use powder sample, so this behavior possibly contains the effect of grain boundary or Anderson localization.

The temperature dependence on electrical resistivity normalized at 280 K from 90 GPa to 150 GPa is shown Figure 5. Above 90 GPa, the slope is negative in all temperature region. Between 100 GPa and 110 GPa, temperature dependence of electrical resistance become positive curvature in all temperature region. Temperature dependence on electrical resistance is not affected by magnetic field at 110 GPa, which is affected at 80 GPa. There is possibility to be the nonmagnetic ($S=0$) state which is expected by first-principle study.

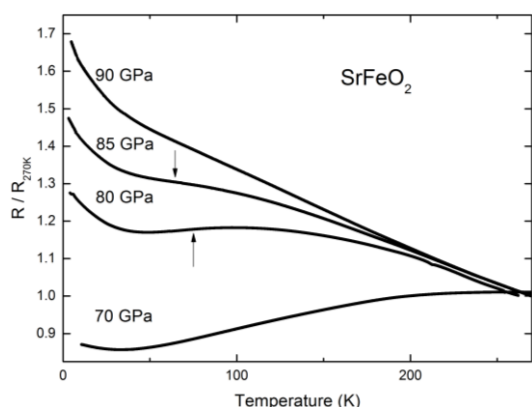


Figure 4. The temperature dependence on electrical resistivity normalized at 280 K from 70 GPa to 90 GPa. The inflection point calculated by 2nd differentiation is pointed by an arrow.

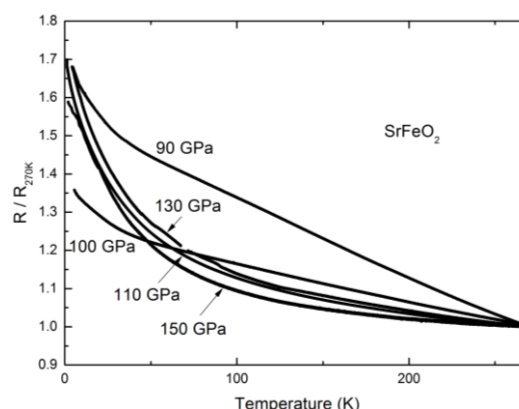


Figure 5. The temperature dependence on electrical resistivity normalized at 280 K from 90 GPa to 150 GPa.

The temperature and pressure dependence on phase diagram drawn by previous research[3] and our measurement is shown in Figure 6. This phase diagram is our result of our research.

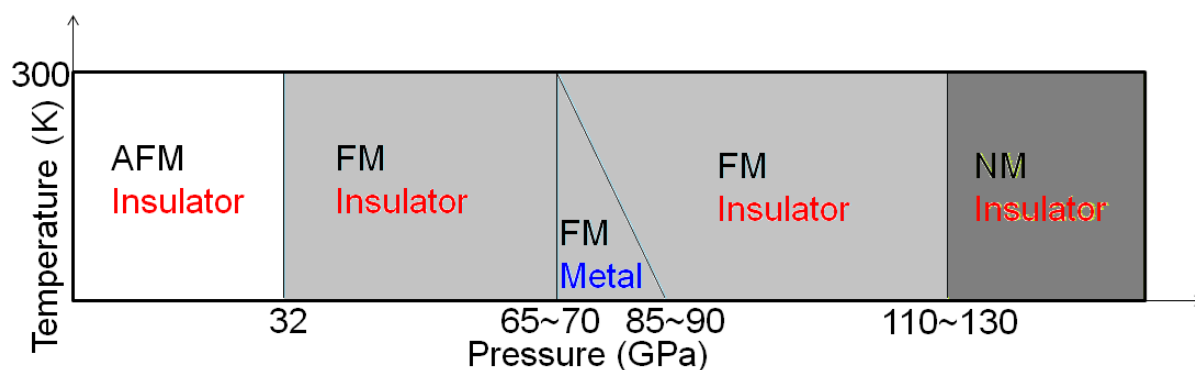


Figure 6. The temperature and pressure dependence on phase diagram.

Acknowledgement

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