# Pressure effects on the superconductivity in $FeSr_2YCu_2O_{7+\delta}$ oxide superconductor

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**Abstract**

We have investigated the pressure dependence of superconducting transition temperature ($T_c$) in $FeSr_2YCu_2O_8$ oxide superconductor (Fe1212). The superconducting Fe1212 samples were synthesized by solid-state reaction with multiple annealing process. The $T_c$-onset of this sample exhibited about 60 K at an ambient pressure. The pressure dependence of $T_c$ was obtained about 2.1 K/GPa up to 2 GPa.

*Key words:* Pressure effect, oxide superconductor, multiple annealing process

## 1. Introduction

The study of substitution of transition elements for copper in the "123" superconductor $YBa_2Cu_3O_y$ is great interest for the understanding of the mechanisms of superconductivity in layered cuprates. For this reason a large number of investigations have been performed that deal with the replacement of copper by iron. In the "123" structural system $YSr_2Cu_3O_y$ phase, Fe can fully substitute the so-called chain site, Cu(1), however, the superconductivity has been reported only in a narrow compositional range of x=0.3 - 0.4 in $(Cu_{1-x}Fe_x)YSr_2Cu_2O_y$. Disappearance of superconductivity in higher Fe concentration, x$\geq$0.5, was believed to be due to the insufficient hole carrier concentration in the material.

Recently, the $FeSr_2YCu_2O_y$ [Fe1212] compounds were found to show superconductivity by applying annealing process under moderately reducing conditions [1]. It is interesting to study the superconducting and magnetic properties of this system with the pressure effects.

In the present work, we have investigated the pressure dependence of the superconducting transition temperature ($T_c$) for the Fe1212 compound.

## 2. Experimental

A polycrystalline sample of Fe1212 was synthesized by solid-state reaction of a stoichiometric mixture of the oxides $Fe_2O_3$, $SrCO_3$, $Y_2O_3$, and CuO. The mixture was calcined at 1173K for 12h and 1223K for 12h in air, ground and then pressed into pellets. The pellets were sintered at 1273K for 24h in air. The sample was subsequently annealed at 1073K for 24h in flowing nitrogen, at 573K for 24h in flowing oxygen, and finally at 623K for 24h in high oxygen pressure of 100atm. The final product was characterized by X-ray diffraction with Cu K$\alpha$ radiation.

The temperature dependence of the resistivity under high pressures was measured using the DC four-probe method up to P = 2.0 GPa. The sample was filled into a Teflon Cell with Daphne oil 7373 (Idemitsu Kosan Co., Japan) as pressure transmitting media and pressurized in a piston-cylinder-type clamp made by NiCrAl ally.

Powder synchrotron X-ray diffraction patterns of this sample were recorded on the Spring-8 beamline BL02B2 at room temperature. The wavelength of the incident X-ray is 0.7757 Å. The diffraction patterns were fitted using the tetragonal $P4/mmm$ symmetry model[2]. We have analyzed the data with profile fit-

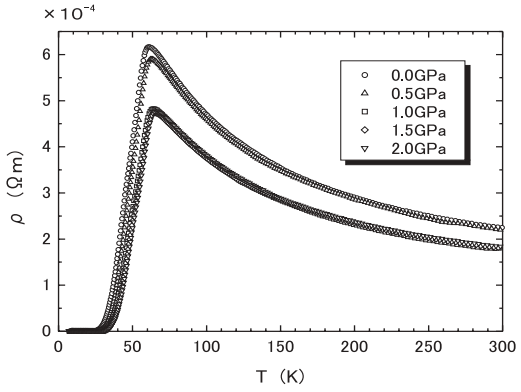


Fig. 1. The temperature dependence of electrical resistivity $FeSr_2YCu_2O_8$ measured at various pressures.

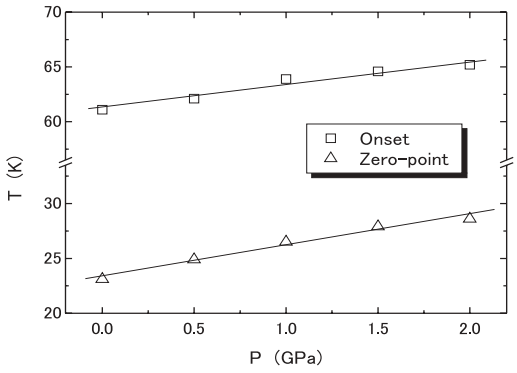


Fig. 2. The pressure dependence of superconducting transition temperature of $FeSr_2YCu_2O_8$.

ting using by RIETAN2000 program [3]. The lattice constants for the sample were $a$ = 3.81679(2) Å, $c$ = 11.3321(1) Å. The result of refinement was almost agreement with the Mochiku's report[2].

## 3. Results and discussion

Figure 1 shows the temperature dependence of resistivity measured at various pressures for Fe1212. At ambient pressure, the value of $T_c$, which is determined from the temperature of zero-resistance, is 23K and the transition is broad. The transition width $\triangle T_c$, defined as the temperature interval over which the resistance dropped from 90 % to 10 % of its value above $T_c$, was about 35K. The broad transition for the Fe1212 was also reported Shimoyama *etal*[1]. A small amount of the incorporation of Fe to the $CuO_2$-plane may lead to the broadening of the transition [1]. With increasing pressure, large changes in the resistivity versus temperature curve are observed. The magnitude of resistivity in the normal state decreased and the value of $T_c$ increased, with increasing pressure. These behaviors of pressure were observed in the under-doped superconducting oxide [4] frequently.

In Fig.2, the value of $T_c$ at the zero-resistance and onset point are plotted as a function of pressure. The pressure coefficient of both the zero-resistance $T_c$ and $T_c$-onset were 2.1 K/GPa and 2.5 K/GPa up to 2 GPa, respectively. The value of the pressure coefficient was nearly agreement with that of Fe-doped $YBa_2Cu_3O_y$ oxide superconductor [5]. It is suggested that this sample of the Fe1212 was due to the small amount of the replacement of Fe to the $CuO_2$-plane and the results of the crystal structure analysis were also supported.

Recently, we have investigated the pressure effects of the $RuSr_2GdCu_2O_8$ (Ru1212) oxide which exhibits the superconducting transition at about 40K and ferromagnetic order at about 130K [6]. The Ru1212 is isostructural with Fe1212 with Fe and Gd being completely replaced by Ru and Y, respectively. The results of the pressure dependence in $T_c$ for Ru1212 show that the $T_c$-onset increases and zero-resistivity temperature decreases with increasing pressure. In other word, the $T_c$'s were scarcely changes and $\triangle T_c$ increased with increasing pressure. The Fe1212 could not be observed the magnetic order above $T_c$ in magnetic susceptibility measurement at least. We must consider the effect of ferromagnetic moment in $RuO_6$ for understanding of the behavior of the pressure dependence of $T_c$ for Ru1212.

In summary, we have investigated the pressure dependence of $T_c$ in Fe1212 superconductor. The $T_c$-onset of this sample exhibited about 60 K at an ambient pressure the and transition is broad. $\triangle T_c$ was about 35K. The pressure dependence of $T_c$ was obtained about 2.1 K/GPa up to 2 GPa.

## References

[1] J. Shimoyama et.al., Physica C **341-348** (2000) 563.

[2] T. Mochiku et.al., J. Phys. Soc. Jpn. **71** (2001) 790.

[3] F. Izumi and T. Ikeda, Mater. Sci. Forum **321-324** (2000) 19.

[4] Y. Yamada et al., Jpn. J. Appl. Phys. **29** (1990) L250.

[5] M. Kurisu et al. Physica C **152** (1988) 339.

[6] Y. Yamada et al., J. Phys. Cond. Mat. (2002) in press.