Pressure effect on a ferromagnetic transition temperature of $RuSr_2GdCu_2O_8$

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Abstract

A number of attention has been paid for $RuSr_2GdCu_2O_8$ because of the coexistance of ferromagnetic state and superconducting state below about 30K. In order to investigate the character of the superconducting state which coexists with ferromagnetism, the pressure experiments on a ferromagnetic transition temperature have been performed. The enhancement of ferromagnetic transition temperature was observed with increasing pressure. High-pressure x-ray experiments on this material are in progress.

Key words: ferromagnetism, superconductivity, pressure effect, Ru1212

1. Introduction

$RuSr_2GdCu_2O_8$(Ru1212) discovered in recent years is an interesting material in which ferromagnetic state and superconducting state coexist. The lattice structure of Ru1212 is similar to that of $YBa_2Cu_3O_{7-\delta}$(YBCO). Ru1212 is derived from the YBCO structure by replacing Y with Gd, Ba with Sr, and the CuO chains with a RuO_2 plane, respectivety. This system was first reported by Bauernfeind *et al.*[1] as superconducting but not magnetic material. However, Ru1212 have a Curie temperature ($T_{\rm Curie}$)‘135K and bulk superconducting transition temperature ($T_{\rm C}$)‘0‘46K, depending on the heat treatment. Although there is a judgment that ferromagnetic impurities $SrRuO_3$ with $T_{\rm Curie}$‘160K is contained[2], feild-induced ferromagnetism was observed by neutron diffraction measurements[3]. It is reported that Ru moments with parallel to *c*-axis incline gradually to *ab*-plane with applying feld. Yamada et al. reported pressure effect on the $T_{\rm C}$ up to 8GPa by electrial resistivity measurements[4]. They observed the onset temperature increase and the offset temperature decreases with applying pressure. However, since the average of onset and offset temperature does not change so much, they indicated that the pressure effect on $T_{\rm C}$ is small and transition width broadened with pressure. Yamada *et al.* synthesized another superconductor $FeSr_2GdCu_2O_8$(Fe1212) with the same crystal structure as Ru1212 in which ferromagnetism does not exist. They observed both onset and offset $T_{\rm C}$ of Fe1212 increase with applying pressure, in contrast to Ru1212. In this work the pressure effect of a ferromagnetic transition temperature has been measured by AC susceptibity method, in order to study the ferromagnetic state and the relation between ferromagnetic and superconducting state.

2. Experiments

$RuSr_2GdCu_2O_8$ was synthesized by solid-state reaction of stoichimetric powders of RuO_2, $SrCO_3$, and CuO. The mixture was first decomposed in air at 950 and heated for 24h. It was pressed into pellets

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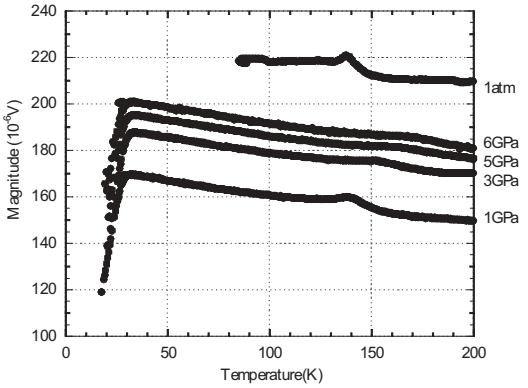

Fig. 1. Temperature dependence of the suscptibility of Ru1212 under various applied pressure.

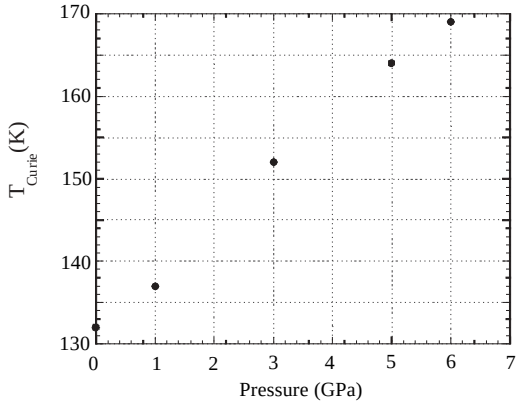

Fig. 2. Pressure dependence of the ferromagnetic transition temperature of Ru1212.

and heated at 960 for 24h in air. Next sintering step took place in flowing nitrogen at 960 for 24h, and heated at 1060for 44h in flowing oxygen. Last sintering step took place in flowing oxygen at 300 under 100atm for 36h. This Ru1212 shows superconducting transition temperature $T_{\rm C}$=40K and ferromagnetic transition temperature $T_{\rm Curie}$=135K. Pressure generating equipment is a cubic-anvil apparatus that was used to generate hydrostatic pressures up to 8GPa at temperatures down to 15K in NIMS. The mixture of Fluorinert FC70 and FC77(1:1) was used for the pressure transmitting medium.

3. Results and Discussion

Figure 1 shows the output signal of AC susceptibility measurements as a function of temperature at each pressures. The sudden change at around 40 K and the cusp at around 140 K correspond to $T_{\rm C}$ and $T_{\rm Curie}$, respectively. The pressure dependence of $T_{\rm C}$ and $T_{\rm Curie}$ are shown in Fig. 2 and Fig. 3. From Fig.2 $T_{\rm Curie}$ increases with pressure at a rate of 6K/GPa. However, this pressure effect is larger than the previous results measured at the magnetic field of 2T[4]. It seems that the ferromagnetic state are strongly affected by the external field. On the other hand, the cusp-shape anomaly accompanied by ferromagnetic transition becomes sluggish at higher pressure. This behavior is considered that the ferromagnetic moment in Ru is suppressed by pressure. Concerning superconductivity, $T_{\rm C}$ does not change so much with applying pressure as shown in Fig.3, which is consistent with the electrical resistivity measurements[4]. Thus this pressure dependence is considered to depend on whether the system has ferromagnetic state or not. High-pressure experiments with changing magnetic field are in progress. High-pressure X-ray measurements for Ru1212 and Fe1212 have been carried out. Precise refinements are now in progress in order to clarify the relation between crystal structure and magnetic properties.

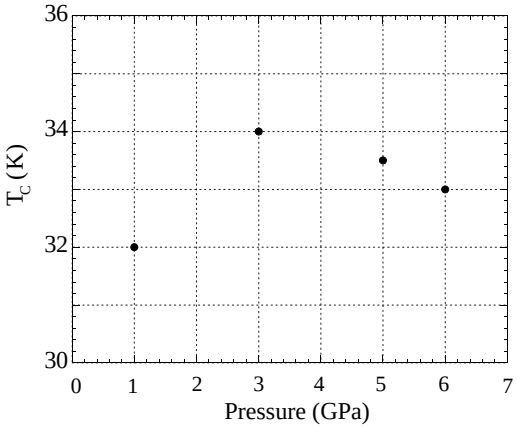

Fig. 3. Pressure dependence of the superconducting transition temperature of Ru1212.

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