ANOMALOUS PRESSURE RESPONSE OF MAGNETIC PROPERTIES IN $RuSr_2GdCu_2O_8$*

G. Oomi, I. Minamitake

Department of Physics, Faculty of Science, Kyushu University
Fukuoka 810-8560, Japan

F. Honda

Department of Electronic Structures, Charles University
Ke Karlovu 5, 121 16 Prague 2, The Czech Republic

M. Kosaka, N. Môri

Department of Physics, Saitama University, Saitama 338-0825, Japan

Do P. Hai, S. Kamizawa and K. Kadowaki

Institute of Materials Science, Tsukuba University, Ibaraki 305-8573, Japan

(Received July 10, 2002)

Electrical resistance and magnetization of $RuSr_2GdCu_2O_8$ have been measured at high pressure in order to clarify the interplay between the magnetic ordering and superconductivity. It is found that the magnetic ordering temperature (T_m) and the superconducting transition temperature (T_C) increase with increasing pressure. These results imply that the superconductivity coexists with magnetic ordering at least up to 2.1 GPa.

PACS numbers: 74.67.Pq, 75.50.Ee, 74.62.Fj

1. Introduction

The hybrid ruthenate-cuprate compound $RuSr_2GdCu_2O_8$ (abbreviated as Ru-1212), in which superconductivity ($T_C \sim 40$ K) and magnetic ordering ($T_m \sim 130$ K) coexist, has attracted much attention because of the possibility to find a new mechanism of superconductivity [1,2]. Since high pressure is

* Presented at the International Conference on Strongly Correlated Electron Systems, (SCES 02), Cracow, Poland, July 10–13, 2002.

well known as a good tool to control the electronic state, it is worthwhile to study the magnetic and electrical properties of Ru-1212 under high pressure. In the present work, we attempted to observe the electrical resistance and magnetization of Ru-1212 under pressure in order to clarify the interplay between magnetic ordering and superconductivity at high pressure.

2. Experimental

The specimens of Ru-1212 were prepared by solid state reaction. High pressure was generated by using piston-cylinder device and a mixture of Fluorinert FC70 and FC77 as a pressure transmitting medium. The details of the present apparatus were described previously [3]. Electrical resistance was measured using standard four-probe method. The magnetization was measured by means of micro high pressure clamp cell and SQUID magnetometer up to about 0.8 GPa [4].

3. Results and discussion

3.1. Effect of pressure on the magnetic transition and superconducting temperatures (T_m and T_C)

Temperature dependent electrical resistance $R(T)$ of Ru-1212 is shown in Fig. 1 at various pressure. $R(T)$ at ambient pressure decreases smoothly with decreasing temperature down to 150 K and shows a small anomaly near 130 K ($= T_m$) due to magnetic ordering followed by a smooth increase in $R(T)$, which is reminiscent of underdoped high T_C superconductors.

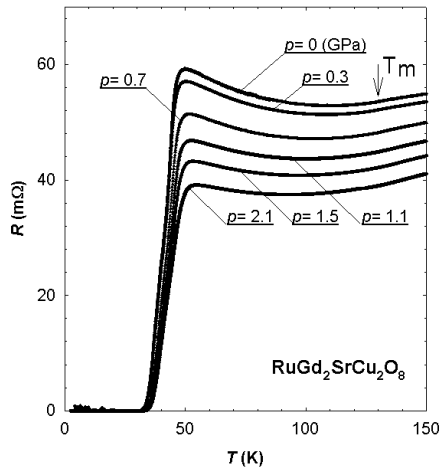

Fig. 1. Temperature dependence of the electrical resistance of Ru-1212 under high pressure. Magnetic ordering temperature T_m is shown by an arrow.

The magnetic transition temperatures T_{m} are defined as a temperature showing a maximum in dR/dT [5]. The same anomaly is found also in the temperature dependence of the thermal expansion coefficients $\alpha(T)$ [6]. After the smooth increase, the $R(T)$ curve shows sudden decrease due to superconducting transition. T_{C} was determined as the temperature having the value of $R = 0.05\,\mathrm{m}\Omega$.

T_{C} and T_{m} are shown in Fig. 2 as a function of pressure. Both T_{C} and T_{m} are found to increase with pressure in almost linear fashion: $\partial T_{\mathrm{m}}/\partial P$ and $\partial T_{\mathrm{C}}/\partial P$ are estimated to be 5.7 K/GPa and 1.6 K/GPa, respectively. These results indicate that both the magnetic interaction and the superconductivity are enhanced by pressure.

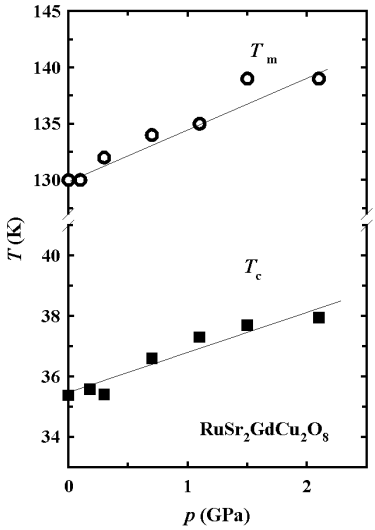

Fig. 2. T_{C} and T_{m} of Ru-1212 as a function of pressure.

3.2. Effect of pressure on the magnetization

Fig. 3 shows the temperature dependence of magnetization M(emu/mol) at 1 kOe at high pressure up to 0.8 GPa. $M(T)$ is almost zero above 170 K but increases steeply near T_{m} due to magnetic ordering. Here we define ΔM as the magnitude of discontinuous change in the magnetization M near T_{m}, which reflects the small ferromagnetic component or the net magnetization of canted antiferromagnetic Ru moment. ΔM is found to decrease as pressure increases. Below 20 K, $M(T)$ increases again due to the magnetic ordering of Gd moment. T_{m} is defined as the temperature where $\chi_{\mathrm{m}}^{-1}(= H/M)$ becomes zero. T_{m} increases with increasing pressure having the rate of about 17 K/GPa, which is larger than that mentioned above. This fact indicates

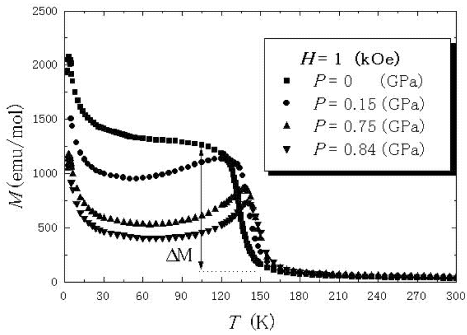

Fig. 3. Temperature dependence of magnetization of Ru-1212 under high pressure.

that ΔM decreases but T_{m} increases by the evolution of antiferromagnetism as pressure increases (see Fig. 4). This fact suggests that the angle between the canted moments decreases at high pressure.

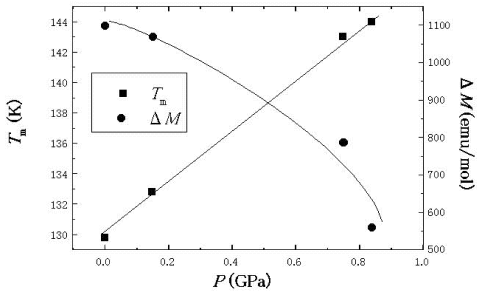

Fig. 4. T_{m} and ΔM of Ru-1212 as a function of pressure. The solid lines are the guide of eyes.

REFERENCES

[1] C. Bernhard, J.L. Tallon, Ch. Niedermayer, Th. Blasius, A. Golnik, E. Brücher, R.K. Kremer, D.R. Noakes, C.E. Stronach, E.J. Ansaldo, *Phys. Rev.* **B59**, 14099 (1999).

[2] J.L. Tallon, C. Bernhard, J.W. Loram, *J. Low. Temp. Phys.* **117**, 823 (1999).

[3] G. Oomi, T. Kagayama, *Physica B* **239**, 191 (1997).

[4] Y. Uwatoko, T. Hotta, E. Matsuoka, H. Mori, T. Ohki, J.L. Sarrao, J.D. Thompson, N. Môri, G. Oomi, *Rev. High Press. Sci. Technol.* **7**, 1508 (1998).

[5] G. Oomi *et al.*, Proceedings of 18th AIRAPT, 2001, Beijing, to be published.

[6] G. Oomi *et al.*, to be submitted.