EFFECT OF PRESSURE ON THE FERROMAGNETIC CERIUM COMPOUND $CeCu_9Sn_4$*

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(Received July 10, 2002)

Electrical resistivity measurements under hydrostatic pressure up to 2.2 GPa was carried out for a ferromagnetic ternary cerium compound $CeCu_9Sn_4$. The ferromagnetic transition temperature increases with increasing pressure up to 0.8 GPa and then decreases with increasing pressure above 1 GPa. Origins of this pressure dependence may be the competition between magnetic interaction in the c-plane and along the c-direction.

PACS numbers: 75.30.Kz, 71.27.+a, 72.15.Jf

1. Introduction

The Ce-based compound $CeCu_9Sn_4$ order ferromagnetically below its Curie temperature $T_C = 5.5$ K [1]. The crystal structure of this compound is tetragonal $LaFe_9Si_4$-type structure [1] derived from the cubic $NaZn_{13}$-type structure of which a heavy fermion compound UBe_{13} is one of the example [2, 3]. And a substituted elements compound $CeCu_{9.4}Sn_{3.6}$ crystallizing in the cubic $NaZn_{13}$-type structure exhibits no magnetic ordering down to 1.6 K [1]. From the view point of the cerium sublattice for the $CeCu_9Sn_4$, the nearest neighbor cerium site is in the c-plane and the second nearest neighbor site is along c-axis. On the other hand, the cerium site distance along the z-direction of $CeCu_{9.4}Sn_{3.6}$ is equal to the nearest neighbor cerium site distance in the xy-plane. This indicate that the energy of the ferromagnetic interaction of the cerium ion in the $CeCu_9Sn_4$ might be determined by the

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

competition between the magnetic interaction within the c-plane and along the c-direction. To clarify the origins of magnetic properties of $CeCu_9Sn_4$, we planned to carry out the pressure effect investigation in this system. In this paper we report the experimental results of the electrical resistivity measurements under high pressure up to 2.2 GPa.

2. Experimental details

The polycrystalline $CeCu_9Sn_4$ sample was obtained by the arc melting method with the starting materials of stoichiometric amounts of the constituent elements and then annealed at 680°C for 32 days. Hydrostatic pressure up to 2.2 GPa was applied using the normal piston cylinder type high pressure apparatus. The 1:1 mixture of Fruorinert FC77 and FC70 was used as a pressure transmitting medium. Actual pressure at low temperature was determined by measuring the superconducting transition temperature of tin for which the pressure dependence of T_C is known to high accuracy.

3. Results and discussions

X ray powder diffraction pattern using Cu Kα (see Fig. 1) showed that the obtained $CeCu_9Sn_4$ samples possess the tetragonal $LaFe_9Si_4$-type structure. The obtained lattice parameters a and c at room temperature by using the Rietveld method with RIETAN program [4] were 8.596Å and 12.34Å, respectively. Fig. 2(a) shows the temperature dependence of the electrical

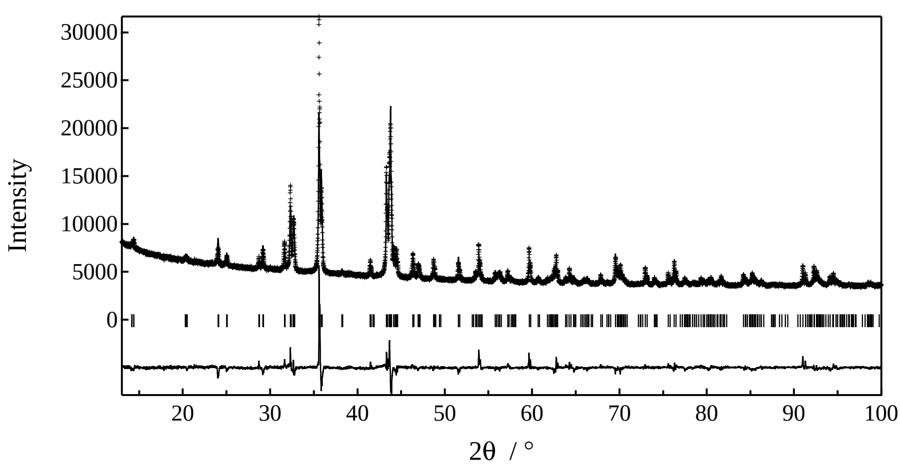

Fig. 1. X ray diffraction pattern using Cu Kα of $CeCu_9Sn_4$ (cross symbols) and calculated pattern by using of Rietveld method [4] (solid line). Lower solid line is the residual curve.

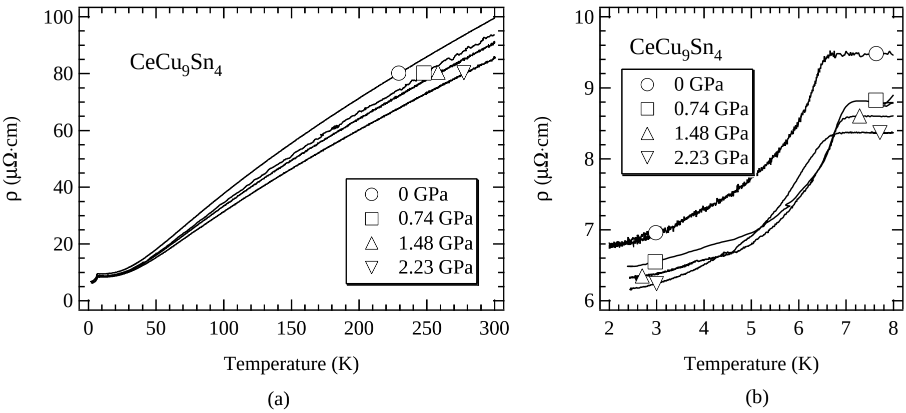

Fig. 2. (a) Temperature dependence of the electrical resistivity of the $CeCu_9Sn_4$ at various pressure. (b) Low temperature part of the temperature dependence of the electrical resistivity of the $CeCu_9Sn_4$ at various pressure.

resistivity of the $CeCu_9Sn_4$ at various pressure. Metallic behavior was observed and the typical features of Kondo effect seems to be not so strong for all pressure region up to 2.2 GPa. Fig. 2(b) is the magnification around at low temperature region. The sharp drop corresponding to the ferromagnetic ordering was observed around 7 K up to 2.2 GPa. The Curie temperature T_C was defined as the temperature at which the temperature derivative of the resistivity become maximum. The pressure dependence of the T_C is shown in Fig 3. The value of T_C increases with increasing pressure up to 0.74 GPa, and above 1 GPa, T_C decreases with increasing pressure. Moreover, as seen in Fig. 2(b), additional new anomaly appeared below T_C, under high pressure region above 1.48 GPa, and this anomaly increases with increasing pressure.

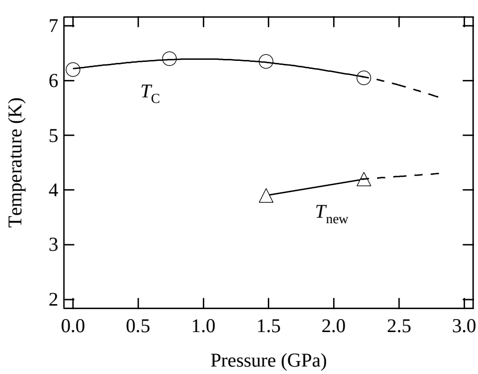

Fig. 3. Pressure dependence of the Curie temperature and new anomalies of the $CeCu_9Sn_4$.

From the temperature dependence of the resistivity, it can be considered that the effect of Kondo screening may be relatively small for the energy of the ferromagnetic interactions in $CeCu_9Sn_4$ under the experimental pressure range. The ferromagnetic interaction may be caused by the extension of c-direction from the cubic structure of the Ce-sublattice since the cubic $CeCu_{9.4}Sn_{3.6}$ is paramagnet down to 1.6 K [1]. By applying pressure, the crystal structure of $CeCu_9Sn_4$ may tend to be restored to the cubic structure, in other words, a compressibility of c-direction of $CeCu_9Sn_4$ may be larger than that of a-direction. Consequently, the magnitude of ferromagnetic interaction under high pressure in $CeCu_9Sn_4$ may be controlled mainly by the intersite distance along c-direction. However, we have no information about the intersite distances of the Ce ions under high pressure. We also need to know the elastic properties of the $CeCu_9Sn_4$. Moreover, the origins of the pressure induced new anomaly is still unknown. Also the possibility of existence of a new magnetic phase, below ferromagnetic phase, must be taken into account. Further investigations are necessary to clarify the magnetic properties of $CeCu_9Sn_4$.

This work is partly supported by a Grant-in-Aid from the Ministry of Education, Science, Sports, and Culture, Japan.

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