Specific Heat of $CeMg_2Cu_9$ with a Two-dimensional Ce Arrangement

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Abstract

We have carried out the specific heat measurements under pressures between 0 and 0.91 GPa on $CeMg_2Cu_9$, in which the Ce atoms are a two-dimensional arrangement. A large peak is observed at $T_N = 2.5$ K for 0 GPa. T_N increases below 0.89 GPa, and turns to decrease with pressurization. The released magnetic entropy S_m below T_N is about 60% of $R\ln 2$ expected for the twofold spin degeneracy, suggesting Kondo-compensated moments are formed in the low temperature range.

Key words: $CeMg_2Cu_9$; specific heat; pressure effect; two dimensionality

In recent years, pressure effects on the intermetallic compounds with a two-dimensional arrangement of Ce atoms have been studied intensively [1,2], since interesting physical properties such as superconductivity emerge because the pressure controls the correlation between electrons. $CeMg_2Cu_9$, which was firstly synthesized by one of the authors (Y. Nakamori), is a good candidate substance with two-dimensional structure, because the nearest neighbor distance along the c-axis between the Ce atoms is almost two-times larger than that in the c-plane [3]. In this paper, we report the results of the specific heat measurements under pressure up to 0.91 GPa on the $CeMg_2Cu_9$.

Polycrystalline samples of $CeMg_2Cu_9$ and $LaMg_2Cu_9$ were prepared by melting stoichiometric amount of consistent metals at 1200°C under about 0.5 MPa Ar atmosphere in a Mo-crucible. Specific heat measurements were carried out by a conventional adiabatic heat-pulse method. A piston-cylinder Cu-Be clamp cell, which contains Apiezon-J oil as pressure-transmitting medium, was used to apply the pressures up to 1 GPa.

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Figure 1(a) shows the temperature dependence of the specific heat divided by temperature C_P/T of $CeMg_2Cu_9$ at ambient pressure in $0.5 < T < 50$ K. A large peak which indicates an antiferromagnetic transition was observed at $T_N = 2.5$ K. The magnetic specific heat C_m was obtained by subtracting a lattice contribution C_l which is estimated from the C_P of the nonmagnetic $LaMg_2Cu_9$, and is shown in Fig. 1(b). The contribution of C_l, for example, is about 0.3 and 90% around 2.5 and 30 K of the total, respectively. A Schottky-type anomaly $C_{\rm Sc}$ due to the effects of the excited crystal-field levels is found around 30 K. A Summerferd coefficient is roughly estimated to be $\gamma \geq 117$ mJ/K^{2}mol from the value of C_m/T at $T = 5$ K. The hexagonal symmetry splits the sixfold degenerate state of Ce^{3+} with $J = 5/2$ into three Kramers doublets with the energy gap Δ_1 and Δ_2 from the ground state. The $C_{\rm Sc}(T)$ is described by

$$C_{\rm Sc}(T) = \frac{Nk_{\rm B}}{T^2}\,[\,\frac{\Delta_1^2 e^{-\Delta_1/k_{\rm B}T} + \Delta_2^2 e^{-\Delta_2/k_{\rm B}T}}{k_{\rm B}^2 Z(T)} - \left(\frac{\Delta_1 e^{-\Delta_1/k_{\rm B}T} + \Delta_2 e^{-\Delta_2/k_{\rm B}T}}{k_{\rm B} Z(T)}\right)^2\,], \qquad (1)$$

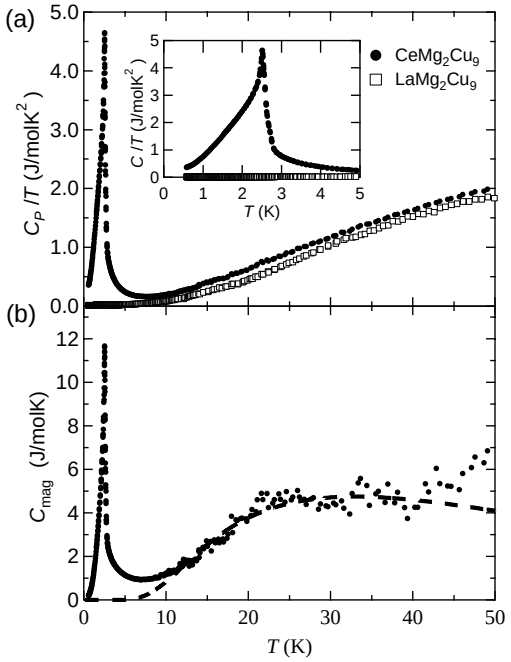

Fig. 1. (a)Temperature dependence of specific heat divided by temperature C_P/T for $CeMg_2Cu_9$. C_P/T of nonmagnetic $LaMg_2Cu_9$ is also plotted. The inset shows that in the low temperature range. (b)Temperature dependence of the magnetic specific heat C_m. The solid line is fitting result using eq. (1).

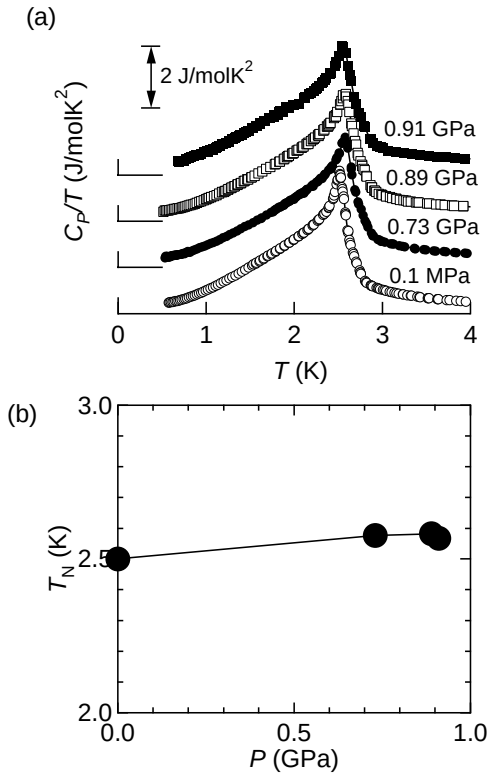

Fig. 2. (a)Temperature dependence of specific heat divided by temperature at applied pressure up to 0.91 GPa. (b)Pressure dependence of T_N. The solid line is a guide to the eye.

with $Z(T) = 1 + \exp(-\Delta_1/k_BT) + \exp(-\Delta_2/k_BT)$ where N and k_B are Avogadro number and Borzman factor, respectively. We estimated the $\Delta_1/k_B = 58$ K and $\Delta_2/k_B = 136$ K from a fit with the equation (1). The fit is shown by the broken line in Fig. 1(b). The released magnetic entropy S_m below T_N obtained by integrating the C_m/T is 60% of the value expected for the twofold spin degeneracy Rln2, where R is the gas constant, suggesting Kondo-compensated ordered moments are formed in the low temperature range.

Figure. 2(a) shows the C_P/T as a function of T at various pressures up to 0.91 GPa in the range $0.5 < T < 4$ K. The Kondo-compensated ordered moments are still formed in the present pressure range, because the value of released S_m below T_N is not changed by pressure very much. T_N slightly increases up to 0.89 GPa, and turns to decrease with pressurization as shown in Fig. 2(b). The two-dimensional Ce arrangement might be play an important role for that.

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