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Letter

Magnetic behaviour of $CePd_2Al$

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Abstract

The results of magnetic susceptibility, heat capacity and electrical resistivity measurements on $CePd_2Al$ suggest that this compound exhibits features attributable to antiferromagnetic ordering (T_N = 3.3 K) and Kondo effect.

Keywords: Magnetic behaviour; Heat capacity; Electrical resistivity; Kondo effect

Recently, several ternary rare-earth (R) compounds of the type, RT_2X (T = transition metals; X = sp metal), have been found to crystallize in three different types of structures [1–3]. Among these, attempts to synthesize YPd_2Si-type (an ordered variant of orthorhombic, Fe_3C) representatives, RPd_2Al, were successful only with R = Ce, Pr and Nd. Hulliger and Xue [2] reported on the basis of magnetic susceptibility (χ) measurements that $CePd_2Al$ does not order magnetically down to 2 K. As a continuation of our investigation (see Ref. [4]) of ternary rare-earth compounds of this stoichiometry, we report here the characterization of $CePd_2Al$ by magnetic susceptibility (χ), heat-capacity (C) and electrical resistivity (ρ) measurements.

The polycrystalline sample of $CePd_2Al$ was prepared by arc melting the constituent elements (minimum 3N grade) in stoichiometric proportions. Barring a few weak peaks (<5%), all the lines in the X-ray diffraction pattern could be indexed to the proper structure. The χ measurements in the temperature interval 2–300 K in a magnetic field (H) of 5 kOe as well as isothermal magnetization (M) measurements at 2 K and 5 K were performed using a superconducting quantum interference device (SQUID). The C data in the temperature interval 2.5–100 K were obtained by a semi-adiabatic heat-pulse method using a set-up fabricated by ourselves [5]. The ρ measurements (2–300 K) were carried out by a conventional four-probe method.

The results of χ and M measurements are shown in Fig. 1. The χ^{-1} is a linear function of temperature (T) in the range 60–300 K and there is a deviation from linearity below 30 K. The effective moment above 60 K is about 2.50 μ_B, typical of trivalent Ce ions and the corresponding paramagnetic Curie temperature (θ_p) is about −23 K. The value of θ_p is reduced to about −10 K below 30 K. As shown in the top inset of Fig. 1, χ^{-1} tends to flatten below about 4 K. In order to

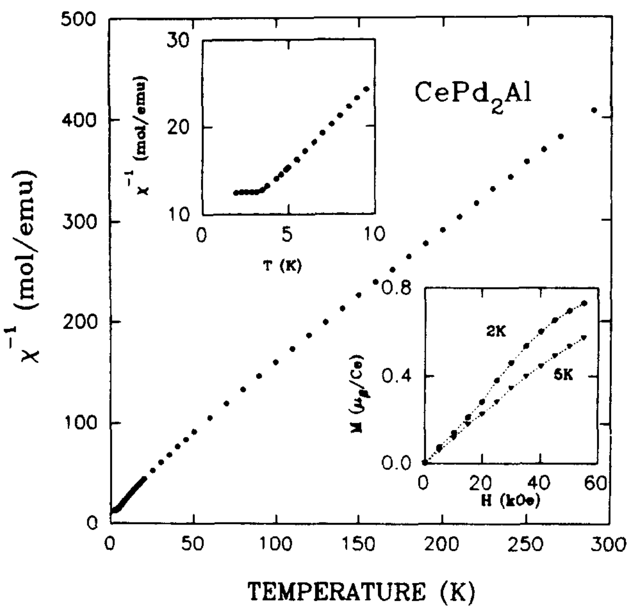

Fig. 1. Inverse susceptibility (χ^{-1}) as a function of temperature for $CePd_2Al$ in the temperature range 2–300 K. The data below 10 K is shown in an expanded form in the top inset. The bottom inset shows isothermal magnetization (M) as a function of magnetic field (H) at 2 K and 5 K.

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probe the nature of the low temperature state, we have performed isothermal magnetization measurements at 2 K and 5 K, the results of which are shown in the bottom inset of Fig. 1. Clearly, M is a non-linear function of H at 2 K, indicating the existence of a spin-flip transition at 20 kOe, a behaviour that is suppressed at 5 K. These observations suggest that this alloy exhibits antiferromagnetic-like ordering well below 4 K. It is to be noted that the magnitude of the low temperature θ_p is quite large compared with the value of the Néel temperature ($T_N = 3.3$ K), thereby indicating that the Kondo effect contributes to θ_p.

In order to confirm the presence of magnetic ordering at 3.3 K, heat capacity measurements were performed. The results below 20 K alone are shown in Fig. 2, as there is no noticeable anomaly above 20 K. There is a sharp increase in C below about 4.0 K followed by a peak at 3.3 K confirming the existence of bulk magnetic ordering. It is rather difficult to quantify whether all the Ce ions order magnetically as (i) the magnetic contribution to C could not be obtained because of the non-existence of the La analogue [2] and (ii) possible persistence of the Kondo effect in the magnetically ordered state can reduce the entropy below 3.3 K. In addition to the peak below 3.3 K, a less intense peak could be seen at 6 K, which may arise from the magnetic ordering from Ce oxides present as an impurity. The plot of C/T vs. T^2 is linear in the temperature range 10–20 K (see Fig. 3) and the linear coefficient (γ) of heat capacity extrapolated to absolute zero is about 110 mJ mol^{-1} K^2. This finding may suggest that this alloy exhibits heavy-fermion behaviour, if there is no influence from the high temperature Schottky peak.

The results of ρ measurements are shown in Fig. 4. There is a ρ minimum at about 14 K, characteristic of

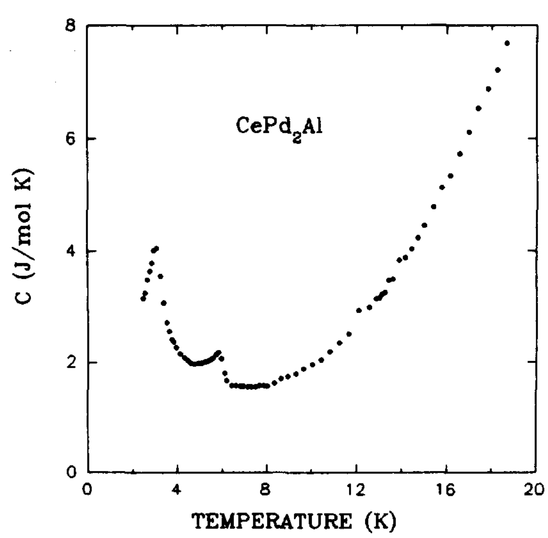

Fig. 2. Heat capacity as a function of temperature (2.5–20 K) for the alloy $CePd_2Al$.

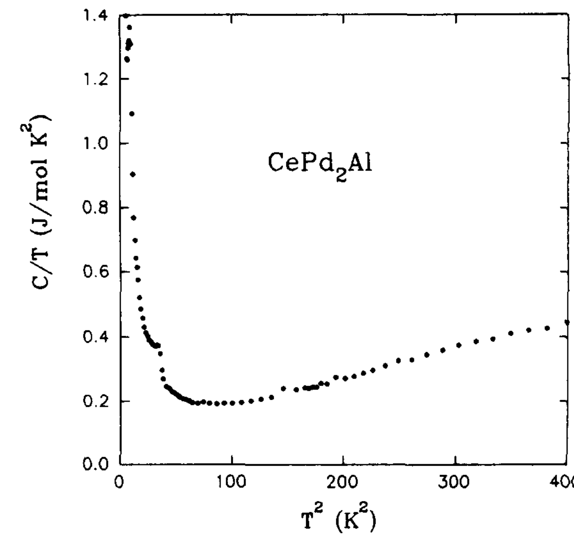

Fig. 3. Heat capacity (C) divided by temperature (T) for the alloy $CePd_2Al$.

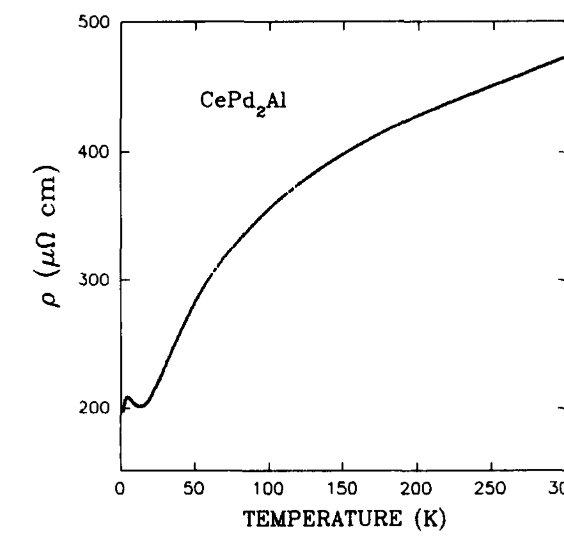

Fig. 4. The electrical resistivity (ρ) as a function of temperature (1.4–300 K) for the alloy $CePd_2Al$.

Kondo effect. A distinct peak at 4 K followed by a drop could be seen attributable to magnetic ordering.

In conclusion, the results of the χ, C and ρ measurements on $CePd_2Al$ suggest that this compound is an antiferromagnetic, Kondo lattice ($T_N = 3.3$ K). It is desirable to verify bulk magnetic ordering by neutron diffraction studies.

Acknowledgments

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