Electrical and magnetic properties of RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) systems

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Abstract

We have investigated the transport and magnetic properties of RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) compounds by means of the AC electrical resistivity ρ and DC magnetic susceptibility χ measurements. Both $\rho(T)$ and $\chi(T)$ data indicate that LaPt_2In_2 and PrPt_2In_2 are non-magnetic above 2 K. The $\rho(T)$ curve for CePt_2In_2 reveals characteristics of a Kondo system with a minimum occurs at 16 K and a logarithmic increase in $\rho(T)$ at lower temperature. The occurrence of a peak in the $\chi(T)$ curve indicates that NdPt_2In_2 undergoes antiferromagnetic transition with $T_N = 3.52$ K. Two magnetic transitions were observed in GdPt_2In_2 with transition temperatures of ~ 50 K and 16 K, respectively.

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1. Introduction

During the past few decades there have been a lot of research activities on the ternary intermetallic compounds because of their interesting properties such as magnetic superconductors and heavy electron systems [1,2]. Recently, it was reported that RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{and Nd}$) compounds crystallize in monoclinic CePt_2In_2 -type structure [3]. To the best of our knowledge, the physical properties of these compounds have not been studied yet till now. In this report, we present our results of the AC electrical resistivity and DC magnetization studies on the RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) systems.

2. Experimental details

The polycrystalline samples of RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) were prepared by arc-melting the high-purity elements (R elements: 99.99%, Pt : 99.99%, In : 99.999%) together in a water-cooled copper hearth in a Zr-gettered argon atmosphere. To improve the sample homogeneity, the as-melted samples were subsequently annealed in argon

atmosphere at 600 °C for 4 weeks. Powder X-ray diffraction patterns reveal that the samples prepared are of the CePt_2In_2 -type structure for $\text{R} = \text{La}, \text{Ce}, \text{Pr}$ and Nd , with the lattice constants close to that of the reported values [3]. AC electrical resistivity of bar-shaped samples has been measured between 4.2 and 300 K in a He^4 cryostat using a four-probe AC technique. DC magnetic susceptibility measurements were performed in a commercial superconducting quantum interference device (SQUID) magnetometer from 2 to 300 K in an applied field of 5000 Oe.

3. Results and discussion

The normalized electrical resistance $R(T)/R(300 \text{ K})$ vs. T curves for the RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) compounds are plotted in Fig. 1 for $0 \text{ K} \leq T \leq 300 \text{ K}$. The $R(T)/R(300 \text{ K})$ curves for these samples exhibit typical characteristics of common metal and decrease monotonically with decreasing temperature T . In addition, a rapid drop in the $\rho(T)$ curve is observed at $T = 14 \text{ K}$ for GdPt_2In_2 , indicating the occurrence of magnetic ordering in this compound. This is shown in the inset of figure, where $\rho(T)$ curves for CePt_2In_2 and GdPt_2In_2 are plotted for $T \leq 30 \text{ K}$. For CePt_2In_2 , the $\rho(T)$ curve reveals characteristic of a Kondo system with a minimum occurs at

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Fig. 1. $R(T)/R(300\text{ K})$ for RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$). The inset depicts the $\rho(T)$ curves for CePt_2In_2 and GdPt_2In_2 for $T < 30\text{ K}$.

16 K and a logarithmic increase in $\rho(T)$ below that temperature. The occurrence of a maximum in the $\rho(T)$ curve at $\sim 4.6\text{ K}$ and saturation of the $\chi(T)$ at low temperature (Fig. 2) confirm that CePt_2In_2 is a Kondo lattice.

Fig. 2 shows the inverse susceptibility χ^{-1} as a function of temperature T for RPt_2In_2 ($\text{R} = \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) measured in an applied field $H = 5\text{ kOe}$ for $0\text{ K} \leq T \leq 300\text{ K}$. The magnetic susceptibility data reveal that both CePt_2In_2 and PrPt_2In_2 are nonmagnetic down to 2 K. While for $T > 100\text{ K}$, χ follows a Curie–Weiss behavior $\chi = C/(T - \Theta_p)$, with $\Theta_p = -16.7$ and -40.2 K for CePt_2In_2 and PrPt_2In_2 , respectively. The effective moment μ_{eff} obtained from the Curie constant $C = N\mu_{\text{eff}}^2/3k_B$ are $\mu_{\text{eff}} = 2.51\mu_B$ per Ce ion and $\mu_{\text{eff}} = 3.52\mu_B$ per Pr ion. The obtained values are close to the values of the moments for the Ce^{3+} ($\mu_{\text{eff}} = 2.54\mu_B$) and Pr^{3+} ($\mu_{\text{eff}} = 3.58\mu_B$) ions.

The magnetic susceptibility curve for NdPt_2In_2 exhibits a peak at $T = 3.52\text{ K}$, which indicates the occurrence of antiferromagnetic transition in this compound. The $\chi(T)$ curve can also be described with Curie–Weiss law for $T > 100\text{ K}$ with $\mu_{\text{eff}} = 3.57\mu_B$ and a Curie–Weiss paramagnetic intercept $\Theta_p = -17.6\text{ K}$.

The $\chi(T)$ curve reveals two magnetic transitions for GdPt_2In_2 . This is shown in the inset of Fig. 2, where $\chi(T)$ curves for NdPt_2In_2 and GdPt_2In_2 are plotted for $0\text{ K} \leq T \leq 100\text{ K}$. A rapid increase of $\chi(T)$ value at $\sim 50\text{ K}$ to a maximum at $T \sim 20\text{ K}$, together with a positive value of $\Theta_p = 25.5\text{ K}$ reveal the occurrence of a ferromagnetic-type

Fig. 2. $1/\chi$ vs. T for RPt_2In_2 ($\text{R} = \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) with the solid lines represent the CW fit for the samples. The inset shows the $\chi(T)$ behavior of the NdPt_2In_2 and GdPt_2In_2 compounds.

transition at $T \sim 50\text{ K}$. In addition, the occurrence of a linear decrease of the $\chi(T)$ at $T = 16\text{ K}$, near the temperature that a rapid drop in the $\rho(T)$ curve is observed for this compound, indicates that antiferromagnetic-type ordering occurs at lower temperature for GdPt_2In_2 .

In summary, we have studied the electrical and magnetic properties of RPt_2In_2 ($\text{R} = \text{La}, \text{Ce}, \text{Pr}, \text{Nd}, \text{and Gd}$) compounds. Both $\rho(T)$ and $\chi(T)$ data indicate that LaPt_2In_2 and PrPt_2In_2 are non-magnetic above 2 K. CePt_2In_2 is a Kondo lattice as inferred from $\rho(T)$ and $\chi(T)$ data. The occurrence of a peak in the $\chi(T)$ curves indicates that antiferromagnetic transition occurs in NdPt_2In_2 at 3.52 K. Two magnetic transitions were observed in GdPt_2In_2 with transition temperatures of $\sim 50\text{ K}$ and 16 K , respectively.

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