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Novel magnetic behavior of single-crystalline Er_2PdSi_3

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Abstract

We report the results of ac and dc magnetic susceptibility (χ) and electrical resistivity (ρ) measurements on the single crystals of Er_2PdSi_3, crystallizing in an AlB_2-derived hexagonal structure, for two orientations $H//[0\,0\,0\,1]$ and $H//[2\,\bar{1}\,\bar{1}\,0]$. For $H//[0\,0\,0\,1]$, there are apparently two magnetic transitions as revealed by the χ_{ac} data, one close to 7 K attributable to antiferromagnetic ordering and the other around 2 K. However, for $H//[2\,\bar{1}\,\bar{1}\,0]$, we observe additional features above 7 K (near 11 and 23 K) in the plot of low field $\chi(T)$; also, there is no corresponding anomaly in the $\rho(T)$ plot. In this respect, the magnetic behavior of this compound is novel, particularly while compared with other members of this series. The features in χ_{ac} respond differently to the application of a small dc magnetic field for the two directions. As far as low-temperature ($T = 1.8$ and 5 K) isothermal magnetization (M) behavior is concerned, it exhibits metamagnetic-like features around 2 kOe saturating at high fields for the former orientation, whereas for the latter, there is no saturation even at 120 kOe. The sign of paramagnetic Curie temperature is different for these two directions. Thus, there is a strong anisotropy in the magnetic behavior. However, interestingly, the $\rho(T)$ plots are found to be essentially isotropic, with the data revealing possible formation of magnetic superzone formation below 7 K.

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Keywords: Er_2PdSi_3; Anisotropy; Metamagnetism; Spin-glass; Magnetization; Electrical transport

Considering interesting properties exhibited (see, for instance, Refs. [1–3] and references cited therein) by the polycrystalline samples of ternary intermetallic compounds derived from AlB_2-type hexagonal structure, we have been carrying out systematic magnetic and transport measurements on the single-crystalline forms of the compounds of the series R_2PdSi_3 [4]. The studies revealed further novel behavior for the single-crystalline

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form [5–10]. In particular, we have noticed a small degree of anisotropy in some properties for the Ho and Dy cases [8,10], while for some others [5,7,9,11] (e.g.$R = \mathrm{Tb}$), the observed anisotropy is stronger, surprisingly even for $R = \mathrm{Gd}$, which is an S-state ion. In addition, probably in all these compounds, there appears to be another magnetic transition [1–3,5–10] at a temperature below the initial magnetic ordering temperature; this second transition though, exhibits "anisotropic spin-glass-like behavior" in macroscopic magnetic measurements, does not appear to arise from a classical spin-glass behavior at least for the Tb case [9] as deduced from recent neutron diffraction data [11]. We have extended single crystal investigations to another heavy rare-earth member of this series, viz., Er_2PdSi_3, and some of the features reported in this article present an interesting situation. It may be mentioned that previous investigations on the polycrystalline samples reveal [4,12] that this compound undergoes antiferromagnetic ordering with a sinusoidally modulated magnetic structure below 7 K with the magnetic moment lying parallel to the c-axis.

Single crystals of Er_2PdSi_3 6–8 mm in diameter and 25–50 mm in length were grown by a vertical floating zone technique with optical heating. The growth process proceeded in a vacuum chamber under flowing Ar atmosphere purified with a Ti-getter furnace. Further details of crystal growth and characterization by the Laue method will be discussed elsewhere [13]. The pieces with requisite dimensions for measurements were cut for two orientations [2 $\bar{1}$ $\bar{1}$ 0] and [0 0 0 1] of the rods. The magnetization (M) measurements (1.8–300 K) were performed employing a commercial superconducting quantum interference device (SQUID, Quantum Design) as well as a vibrating sample magnetometer (Oxford Instruments). The same SQUID magnetometer was employed to take ac magnetic susceptibility (χ_{ac}) data below 25 K at various frequencies. The electrical resistivity (ρ) measurements were performed by a conventional four-probe method employing spring-loaded sharp gold-plated copper tips for making electrical contacts with the sample.

The temperature (T) dependence of dc magnetic susceptibility (χ_{dc}) at low temperatures taken in the presence of magnetic fields (H) of 5 kOe and 100 Oe for the two orientations are shown in Figs. 1 and 2, respectively. For both the orientations, the plots of inverse χ_{dc} versus T taken with $H = 5$ kOe is linear above 70 K. The value of the effective moment ($9.6\mu_B$/Er) obtained from the high-temperature linear region is very close to that expected for trivalent Er ions. The χ_{dc} shows a continuous (but weak) deviation from the Curie–Weiss law as the T is lowered below 70 K for the $H//[2\,\bar{1}\,\bar{1}\,0]$ orientation. For $H//[0\,0\,0\,1]$, the Curie–Weiss law however extends down to 30 K. We attribute the deviation from the linear behavior to crystal field and/or short-range order effects. In the following, we bring out the anisotropy in the χ_{dc} behavior including the anisotropic onset of short-range magnetic correlations:

For $H//[0\,0\,0\,1]$, the Curie–Weiss temperature (θ_p^c) obtained from the linear region above 100 K is found to be 16 K, as though the magnetic coupling

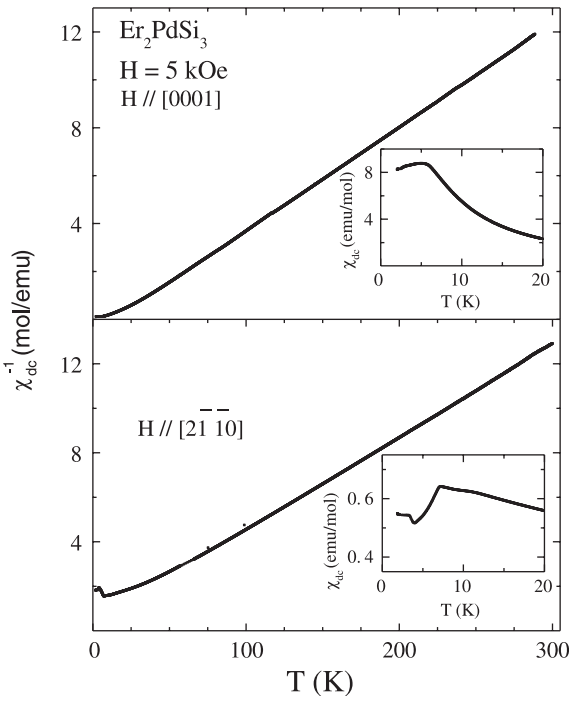

Fig. 1. Inverse dc susceptibility as a function of temperature for two orientations of the single crystal of Er_2PdSi_3 with respect to the magnetic field of 5 kOe. The low-temperature χ behavior is shown in the inset.