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Magnetic Phase Transition in $CePd_2P_2$

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The tetragonal $CePd_2P_2$ compound has been investigated by ac magnetic susceptibility and dc magnetization measurements. The experimental data reveal a ferromagnetic phase transition at $T_C = 28.4 \pm 0.2$ K. Using Arrot-Noakes plot and scaling laws for a second-order phase transition, critical exponents for the ferromagnetic transition in the system were obtained. The critical exponents are located between those of the mean field and Heisenberg model values.

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1. Introduction

Intermetallic compounds with the tetragonal $ThCr_2Si_2$-type structure attract wide interest owing to their large variety of exotic physical properties, such as complex magnetic order [1], Kondo effect, or heavy-fermion superconductivity [2]. In the case of Ce-based compounds, magnetic ground state is governed by the hybridization of the 4f-electrons with the conduction electrons. Amongst the series of compounds CeT_2M_2 (T= d-electron transition metal, M= p-electron element), in most cases the local magnetic moments of Ce^{3+} ions order antiferromagnetically. Although $CeRu_2Ge_2$ is the only one, which undergoes as much as two phase transitions; a ferromagnetic at $T_C \sim 7.4$ K and an antiferromagnetic one at $T_N = 8.5$ K [3]. Recently, the interest in intermetallic compounds of the tetragonal 122-type has been renewed owing to the discovery of high-Tc superconductivity in FeAs-based pnictides [4].

$CePd_2P_2$ was reported to crystallize in the $ThCr_2Si_2$-type structure by Jeitschko and Hofmann many years ago [5]. To the best of our knowledge, no information on physical properties is available in the literature. Thus we have undertaken investigations of magnetic properties of this compound. The preliminary results of our study are presented in this contribution.

2. Experimental details

The polycrystalline sample of $CePd_2P_2$ was prepared by the standard solid-state reaction. First, CeP and Pd_2P were synthesized by heating pieces of Ce or Pd with red phosphorus in evacuated and sealed silica ampoules. Then, CeP and Pd_2P were mixed in a stoichiometric ratio and pressed into pellet in an Ar filled glove box. The pellet was put into an alumina crucible, sealed in evacuated silica tubes and heated at 950 °C for 10 days. The powder x-ray diffraction technique was used to check phase purity and to determine the lattice parameters. The refinement of all observed Bragg peaks confirmed the tetragonal $ThCr_2Si_2$-type structure. The lattice parameters of our $CePd_2P_2$ sample are $a = 0.41762$ nm and $c = 0.95093$ nm and are different by about 2% from the previously reported values ($a = 0.4156$ nm and $c = 0.9887$ nm [5]).

Measurements of ac magnetic susceptibility and dc magnetization were performed in the temperature range 2 –50 K using a Quantum Design PPMS platform. Ac driving field amplitude of 10 Oe and frequencies up to 1 kHz were applied. The dc measurement was conducted in external magnetic fields up to 5.5 T.

3. Results

In Fig. 1 we show the temperature dependence of real $\chi\prime(T)$ and imaginary $\chi\prime\prime(T)$ components of the ac susceptibility measured in several external magnetic fields $\mu_0 H$. With decreasing temperature, a pronounced maximum at $T_C = 28.2$ K is observed in the 0 T - $\chi\prime(T)$ curve (Fig. 1a). Such a behaviour indicates the onset of a ferromagnetic ordering. With further cooling of the sample, $\chi\prime(T)$ shows a stronger decrease below 10 K, accompanied by a knee in the $\chi\prime\prime(T)$ component (Fig. 1b).

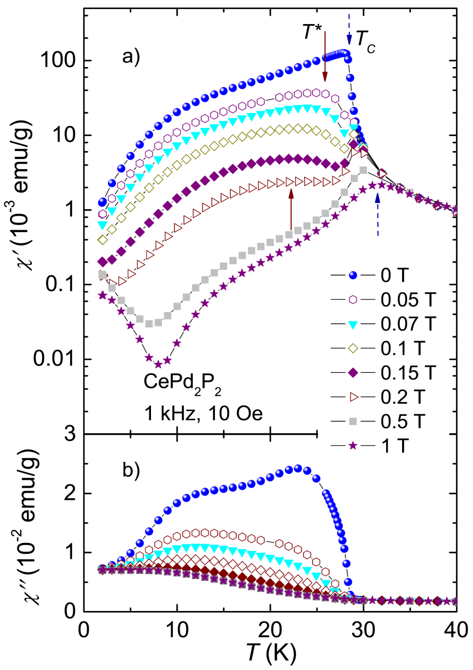

Fig. 1. ac susceptibility of $CePd_2P_2$ in several external fields as a function of temperature.

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Interestingly, application of external fields above 0.05 T splits the $\chi\prime(T)$-maximum into two anomalies denoted by dashed and solid arrows at T_C and T^*, respectively. As can be seen, the temperature of the anomaly, associated with the ferromagnetic phase transition, increases with increasing fields, whereas a broad maximum at $T^* < T_C$ shifts down to lower temperatures. Unfortunately, the microscopic mechanism of the latter anomaly is unknown at present, probably it is the effect of the local change of the slope of dM/dH with the temperature.

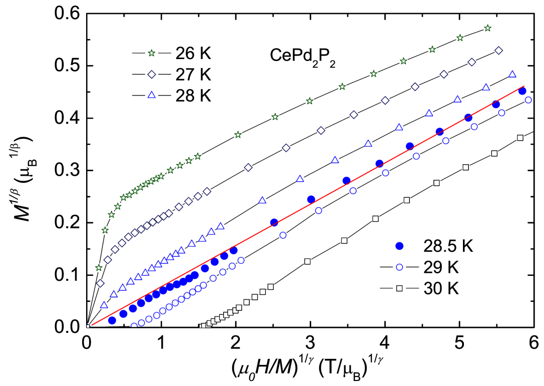

Fig. 2. The Arrott-Noakes plot for $CePd_2P_2$.

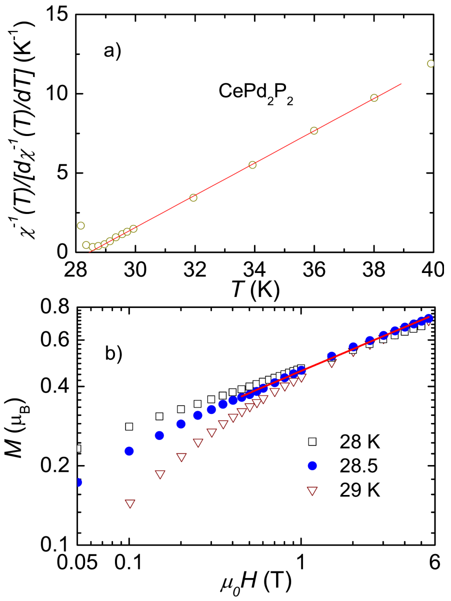

Fig. 3. a) The Kouvel-Fisher and b) M vs H plot for $CePd_2P_2$.

We may confirm the Curie temperature by plotting the dc-magnetization data around T_C in the form: $(H/M)^{1/\gamma} = (T-T_C)/T_C+(M/M_0)^{1/\beta}$, where T_C, M_0, γ and β are parameters which can be obtained from fitting the data. The best fit of the data yields $\beta = 0.405 \pm 0.005$ and $\gamma = 1.15 \pm 0.05$. The critical exponent γ can be directly determined from the magnetic susceptibility for $T > T_C$ via the relation: $\chi(T)^{-1} \propto [(T-T_C)/T_C]^\gamma$. To estimate the exponent γ we used the method proposed by Kouvel and Fisher (KF) [7], who showed that the temperature dependence of the ratio $\chi(T)^{-1}/[d\chi(T)^{-1}/dT]$ should give straight line with slope $1/\gamma$.

The KF linear fitting of the 0 T - $\chi\prime(T)$ data shown in Fig. 3a gives the exponent $\gamma = 1.031$. An average value of γ estimated from the two fittings is 1.09 ($\pm$ 0.05). The critical exponents β and γ are related to another critical exponent δ through the Widom scaling relation: $\delta = 1+\gamma/\beta$, where exponent δ appears in the relationship between M and H at T_C as $M = AH^{1/\delta}$ [9], where A is a constant. We obtained the value of $\delta = 3.7037$ from the slope of the isotherm at 28.5 K as M vs. H on a log-log scale (solid line in Fig. 3b). Consequently, the obtained values of the critical exponents $\beta = 0.405$, $\gamma = 1.09$ and $\delta = 3.69$ are reliable and in good agreement with the scaling hypothesis ($\delta = 3.7037$). We may recall that in the 3D-systems, the mean field theory predicts $\beta = 0.5$ and $\gamma = 1$, while the classical Heisenberg model anticipates $\beta = 0.38$ and $\gamma = 1.375$ [10]. Apparently, our experimental values are located between those of the mean field and Heisenberg model values.

4. Conclusions

We found a ferromagnetic order below $T_C = 28.4$ K in the tetragonal $CePd_2P_2$ compound. The critical exponents, $\beta = 0.405$, $\gamma = 1.09$ and $\delta = 3.69$, have been determined based on various research techniques including Arrott-Noakes plot, Kouvel-Fisher method, and critical isotherm analysis. These values are located between those of the mean field and Heisenberg model values.

Acknowledgements

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