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Magnetic field dependence of the non-Fermi-liquid state in ferromagnetic $CePd_{1-x}Ni_x$

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Abstract

The results of measurements of the electrical resistivity (ρ), specific heat (C), and magnetic susceptibility (χ) are reported for compounds near the ferromagnetic transition in the $CePd_{1-x}Ni_x$ system. The magnetoresistance is large and positive at low temperatures. The zero-field non-Fermi-liquid characteristics of $\rho(T)$ and of $C(T)$ are shown to be modified in an applied field.

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Keywords: $CePd_{1-x}Ni_x$; Non-Fermi-liquid; Magnetoresistivity; Magnetic susceptibility; Specific heat

The pseudobinary $CePd_{1-x}Ni_x$ system shows interesting non-Fermi-liquid behaviour [1]. The parent compound CePd orders into the ferromagnetic state at $T = 6.6$ K [2] with a high-temperature effective magnetic moment of 2.50 μ_B which is very close to the full Hund's rule 4f-configuration moment value. On the other hand, CeNi shows clear thermodynamic and transport characteristics of an intermediate valent (IV) metal [3]. In $CePd_{1-x}Ni_x$, the orthorhombic CrB-type structure was found to persist throughout the entire concentration range [2]. Since Pd and Ni are approximately isoelectronic d-electron metals, their systematic substitution in $CePd_{1-x}Ni_x$ can be expected to represent a controlled variation in the cerium interionic distance. The sensitive balance between the IV state and the FM state was shown [3] to lead to a narrow concentration range that displays non-Fermi-liquid (nFL) behaviour.

In the present study we report on measurements to investigate the magnetic field dependence of the nFL state of $CePd_{1-x}Ni_x$. Samples with $0.92 \leqslant x \leqslant 0.955$, together with LaNi were prepared by arc-melting of stoichiometric quantities of Ce, La, and Pd (99.99 wt%) and Ni (99.95 wt%) in an ultrahigh-purity argon atmosphere. No further heat treatment was given. The samples were all checked using powder X-ray diffraction and verified to have formed in the expected crystal structure, free from parasitic phases and unreacted material.

Fig. 1 shows the temperature dependence of the magnetic susceptibility, $\chi(T)$, for several compounds in the $CePd_{1-x}Ni_x$ system. The data are plotted against $T^{0.75}$ to emphasize the development of a power-law below ~ 5 K for compounds near the critical point. Measurements of $\chi(T,B)$ are needed at lower temperatures in order to investigate the possible extension of this observed power-law behaviour. Fig. 2 shows the main features of the temperature dependence of the cerium 4f-electron electrical resistivity, $\rho_{4f}(T,B)$ that is obtained by subtracting $\rho_{LaNi}(T,B)$ from the measured $\rho(T,B)$ data, for various values of applied field on $CePd_{0.06}Ni_{0.94}$. Nieva et al. [2] indicated ferromagnetic ordering for their 6% Pd compound, while in our series of compounds $CePd_{0.06}Ni_{0.94}$ was found to be the highest Pd concentration that did not show any anomaly

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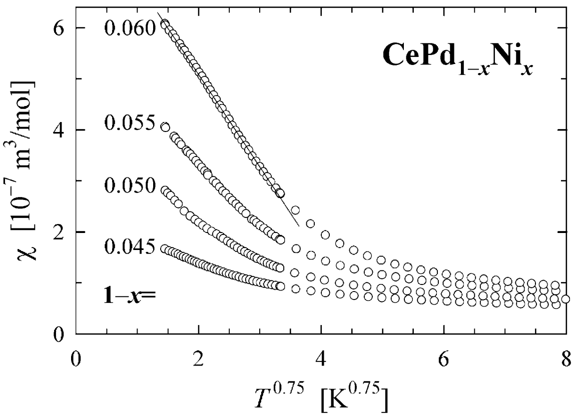

Fig. 1. Magnetic susceptibility vs. $T^{0.75}$ for various $CePd_{1-x}Ni_x$ compounds. The straight line is a guide to the eye.

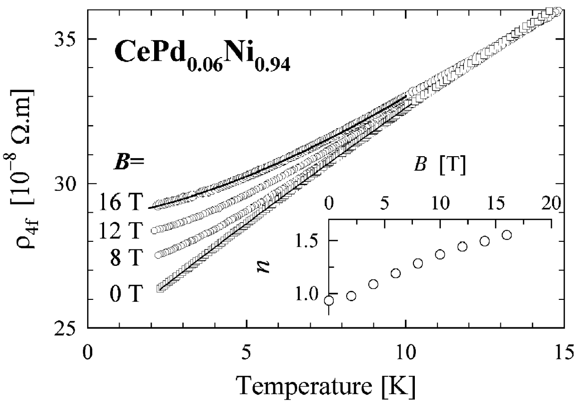

Fig. 2. Electrical resistivity vs. temperature. The solid lines represent least-squares fits to the data (see text) the temperature exponent of which is plotted in the inset against applied field.

in AC-susceptibility data down to 1.78 K (not shown), and hence we analyze this particular compound as being just at the edge of a ferromagnetic transition. We note that the ρ values are increased by an applied field, indicating an anomalous positive magnetoresistivity (MR) for this system. Weak and nearly ferromagnetic metals are expected to show negative MR, in response to suppression of spin fluctuations [4]. There is a clear evolution seen in the power-law dependence, $\rho(T \lesssim 10\ \mathrm{K}) = \rho_0 + AT^n$ (see solid lines in Fig. 2) for

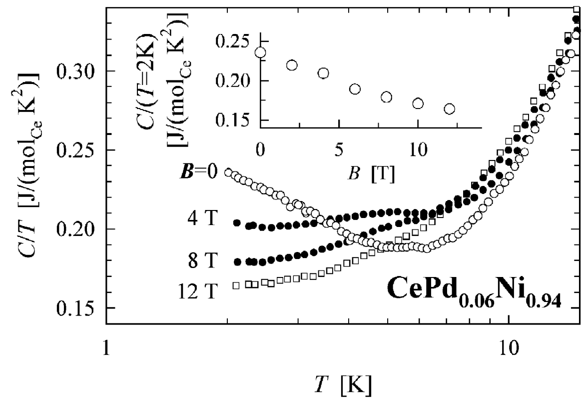

Fig. 3. Specific heat data vs. temperature for various applied fields. The values of $C/(T = 2\ \mathrm{K})$ are plotted in the inset to illustrate the evolution with field.

isofield curves between zero field and $B = 16$ T. The inset to Fig. 2 plots the steady increase of the n-exponent with field. For high fields, the exponent reaches $n = 1.55(1)$, a value which is close to the $\rho \sim T^{5/3}$ behaviour predicted for $\rho(T)$ very near the ferromagnetic transition [4]. This supports an interpretation of the applied field inducing ferromagnetic spin alignment.

In Fig. 3 specific heat data are plotted in the main figure on semi-log axes to reveal the $C/T \sim \ln T$ behaviour in zero field, as was also found by Kappler et al. [1]. The applied magnetic field is mainly found to cause a suppression of the low-temperature enhancement of C/T, which is probably due to the magnetic field lifting the strongly correlated spin degeneracy. As a result, the $B = 12$ T data of C/T enters near-saturation towards low temperatures, which could be reconciled with a Fermi-liquid ground state. The inset of Fig. 3 illustrates the $\approx 30\%$ decrease in the $C/(T = 2\ \mathrm{K})$ measured values when applying a field of $B = 12$ T.

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