

# Ground state properties of $\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{Ge}_2$ and $\text{CeNi}_2(\text{Ge}_{1-y}\text{Si}_y)_2$

G. Knebel\*, M. Brando, J. Hemberger, M. Nicklas, W. Trinkl, A. Loidl

*Experimentalphysik V, Elektronische Korrelationen und Magnetismus, Universität Augsburg, 86159 Augsburg, Germany*

The ground state properties of heavy-fermion systems (HFS) can be described in the framework of Doniach's phase diagram [1]. In recent years the transition region from magnetic order to a non-magnetic Kondo-like groundstate has found renewed interest due to the appearance of non-Fermi-liquid (NFL) behavior in this regime [2]. The aim of this work is to change the hybridization strength via isoelectronic chemical substitutions and to pass continuously from a system with local-moment magnetism (LMM) to the intermediate-valence (IV) regime, paying special attention to the critical concentration where magnetism is completely suppressed. For these investigations we performed systematic electrical resistivity, magnetic susceptibility and specific heat experiments for temperatures  $0.06 \text{ K} < T < 400 \text{ K}$  and in magnetic fields up to  $14 T$  on the ternary alloys  $\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{Ge}_2$  and  $\text{CeNi}_2(\text{Ge}_{1-y}\text{Si}_y)_2$  which crystallize in the  $\text{ThCr}_2\text{Si}_2$  structure.  $\text{CePd}_2\text{Ge}_2$  is a local-moment magnet with an antiferromagnetic (AFM) phase transition temperature of  $T_N = 5.2 \text{ K}$ . The size of the ordered moment,  $\mu_s = 1.79\mu_B$ , shows that moment

compensation plays a minor role [3].  $\text{CeNi}_2\text{Ge}_2$  is a non-magnetic HFS with a characteristic Kondo-lattice temperature  $T^* = 40 \text{ K}$  [4]. Finally  $\text{CeNi}_2\text{Si}_2$  is a IV system with  $T^* \approx 600 \text{ K}$  [5].

Fig. 1 shows the dependence of the characteristic temperatures of the alloys under investigation on the hybridization strength between f moments and band states. Our systematic studies provide evidence that the distance  $r$  between the 4f ions and the transition metals is the relevant parameter. Accordingly we plotted  $T^*$ ,  $T_N$  and the Curie-Weiss temperature  $\theta_p$  as a function of  $r$ .  $T^*$  was determined from the coherence maximum of the resistivity for low Kondo temperatures and from the peak in the magnetic susceptibility for the alloys with strong hybridization. Fig. 1 clearly shows that  $T_N$  and  $T^*$  are of the same order of magnitude on the Pd-rich side of the phase diagram. However,  $T^*$  strongly increases at the borderline from AFM order to the pure Kondo ground state. In a similar way,  $\theta_p$  is strongly enhanced when the Kondo interaction starts to dominate. At the phase boundary from magnetic order to Kondo behavior strong NFL effects were observed in the temperature dependence of heat capacity, resistivity and magnetic susceptibility (shaded area in Fig. 1).

The low temperature electrical resistivity has been analyzed using  $\rho = \rho_0 + AT^n$ . The coefficient  $A \propto$

\*Corresponding author. Tel.: +49-821-598-3614; fax: +49-821-598-3649; e-mail: georg.knebel@physik.uni-augsburg.de.

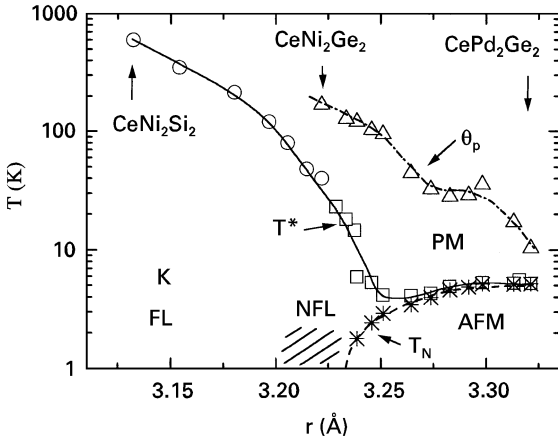


Fig. 1. Dependence of the characteristic temperature  $T^*$ , the Néel temperature  $T_N$  and the paramagnetic Curie-Weiss temperature  $\theta_p$  as a function of the cerium-transition metal distance  $r$ . The hatched area shows the regime where NFL behavior is observed.

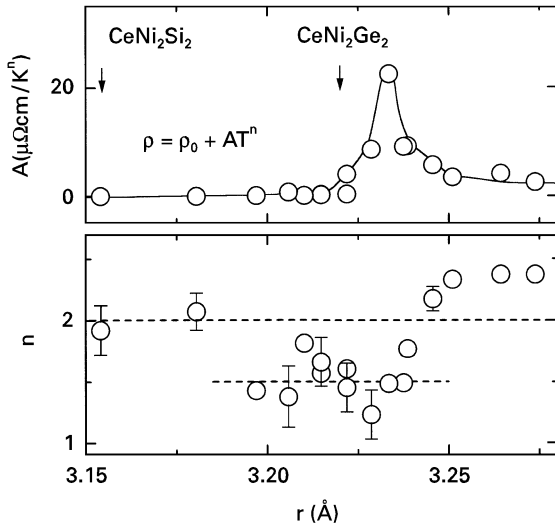


Fig. 2. Prefactor  $A$  and temperature exponent  $n$  of the low-temperature resistivity  $\rho = \rho_0 + AT^n$  versus the cerium ligand distance  $r$ . The lines at  $n = 2$  and  $n = 1.5$  are drawn to guide the eye.

$(N(E_F))^2$  is only well defined for a Fermi liquid ( $n = 2$ ) due to scattering of heavy quasiparticles. Just at the critical concentration where magnetic order is suppressed the temperature range where the  $T^2$  law holds becomes very small and  $A$  is expected to diverge. However, in this regime  $\rho(T)$  can be described by a power law with  $n \neq 2$  for more than one decade in temperature.  $A$  reveals a maximum for  $\text{Ce}(\text{Pd}_{0.1}\text{Ni}_{0.9})_2\text{Ge}_2$  (see Fig. 2). We would like to state that this analysis is a mere parametrization of the data. However, the maximum in  $A$  is also recovered with  $n = 2$ , with fits which are significantly worse. In the Kondo regime  $n$  approaches 2 as is expected for pure Fermi liquids. It is significantly larger than 2 for the magnetically ordered compounds but it is approximately 1.5 in a broad concentration regime close to the critical regime. This size of the exponent has been predicted by Ref. [6] for a AFM NFL.

## References

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