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The influence of coherence in CePtSi

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Abstract

In order to investigate the recently observed "coherence" effect of the non-f-atom site in $CeCu_2Si_2$, we present here a similar study on $CePt_{1-x}Ni_xSi$ to investigate further if there is a universal role of coherence in heavy fermion systems. Although the work on $CeCu_2Si_2$ could not decide between the two possible explanations, our results tend to favor a Kondo resonance instead of a magnetic correlation model to describe the high effective mass.

Keywords: Heavy fermion; Kondo lattice; Magnetic correlation; Coherence; Ce compounds

1. Introduction

We have recently discovered that interruption of the non-f-atom Cu-site in $CeCu_2Si_2$ drastically reduces the heavy fermion effective mass m^*, independent of the electronic character of the dopant [1]. The heavy fermion system CePtSi, discovered in 1987 by Lee and Shelton [2], is described as a coherent Kondo lattice compound with a very large Sommerfeld coefficient γ and low-temperature magnetic susceptibility $\chi(T=0$ K) of around 24 memu mol^{-1}. This system, which crystallizes in the tetragonal LaPtSi structure [3], shows no superconducting or magnetic transition down to 70 mK [2,4]. Although doping on the Si sites with Ge, Ga and Al leads to an antiferromagnetic state [5,6], Lee et al. [7], based on their low-temperature susceptibility and resistivity measurements on $CePt_{1-x}Ni_xSi$, did not observe any magnetic ordering in this latter compound. Thus, $CePt_{1-x}Ni_xSi$ is an ideal system to investigate further the role of non-f-atom-sublattice coherence for the formation of the heavy fermion ground state. Therefore, we report here for the first time specific heat measurements on $CePt_{1-x}Ni_xSi$.

2. Results

Measurements of powder X-ray diffraction, magnetization (in fields up to 7 T at 2 K), and susceptibility (1.65 K $\leq T \leq$ 400 K at 0.5 T) all showed the same behavior as reported in Refs. [7,8], i.e. none of the samples showed magnetic behavior. This is confirmed by our specific heat measurements (see Fig. 1), which were not previously [7,8] reported.

The specific heat measurements were performed using a relaxation method [9,10] and have an accuracy of ± 3%. Fig. 1 displays several representative specific heat curves for $CePt_{1-x}Ni_xSi$. At high temperatures all samples showed the behavior of a classical metal, i.e. $C = \gamma T + \beta T^3$. After a local minimum the specific heat divided by temperature increases at low temperatures. This increase cannot be described by a spin

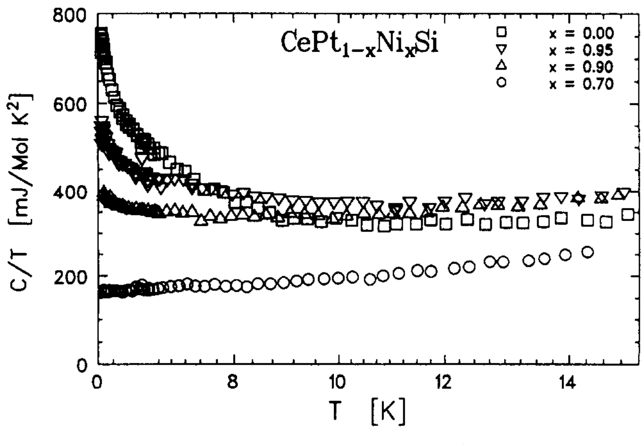

Fig. 1. Specific heat measurements on $CePt_{1-x}Ni_xSi$ plotted as C/T vs. T^2. Our error bar is ± 3%, or approximately the size of the symbols.

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fluctuation ($C \sim T^3\ln(T)$) or non-Fermi liquid model ($C \sim T\ln(T)$). With increasing Ni doping γ ($\equiv C/T$ as $T \rightarrow 0$), which is proportional to the effective mass m^*, decreased as shown in Fig. 2. The decrease observed for $x \leq 0.2$ is quite rapid; at 20% doping γ was only 30% of $\gamma(x = 0)$.

Interestingly, this is nearly the same percentage decrease in γ as in $CeCu_2Si_2$, also shown in Fig. 2. Although CePtSi and $CeCu_2Si_2$ were doped with different transition elements, the results were the same within a small scatter. Also, owing to the varying sizes of the dopants, this effect cannot be explained by an influence of the lattice parameters. Thus, an uninterrupted lattice of non-f-atoms plays the same important role for the formation of m^* in CePtSi as was seen in $CeCu_2Si_2$ [1].

Mielke et al. [1] were not able to decide between two explanations for the decrease in γ and its effects on the coherence. One model is described by Aeppli and Broholm [11], where heavy fermion systems are explained by magnetic correlations and the decrease in γ is explained by suppression of these magnetic correlations. The other model, invoked in Ref. [1], explained the heavy fermion system as a coherent

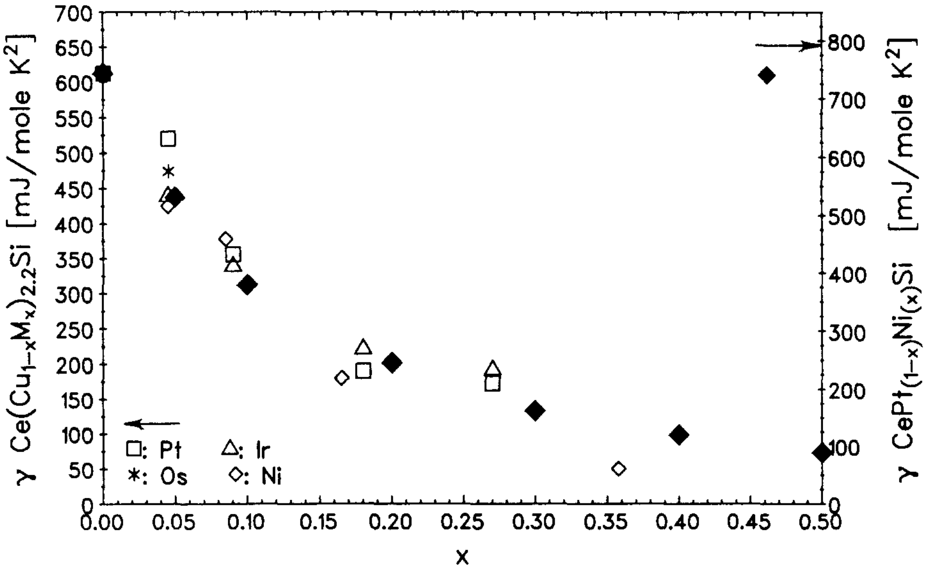

Fig. 2. The Sommerfeld coefficient γ of $Ce(Cu_{1-x}M_x)_{2.2}Si_2$ [1] and $CePt_{1-x}Ni_xSi$ at $T = 1.25$ K. Both systems show the same percentage decrease as a function of x. This lends further support to a universal role of coherence in heavy fermion systems.

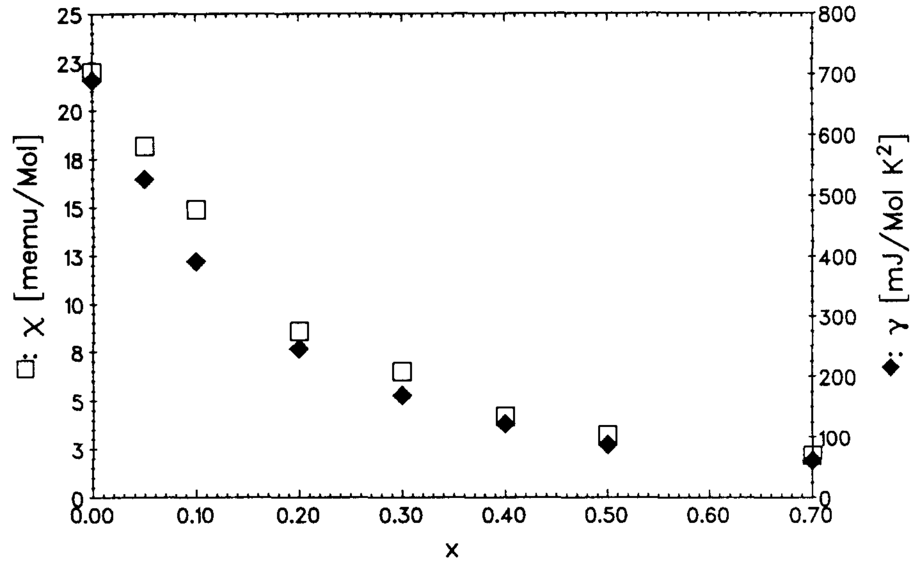

Fig. 3. Magnetic susceptibility χ and Sommerfeld coefficient γ of $CePt_{1-x}Ni_xSi$ showing nearly the same decrease with increasing Ni concentration.

Kondo lattice [12]. In this model a breakdown of coherence will reduce γ because of a broadening of the resonance of the electronic density of states. This latter picture is supported by our $\chi(T)$ measurements that showed the same progress in CePt$_{1-x}$Ni$_x$Si as γ (Fig. 3). Together with unsaturated magnetization curves of the doped samples this is a strong hint that both χ and γ mainly reflect a lowering of the density of states of the conduction electrons at the Fermi level rather than reduced magnetic correlations.

In conclusion, we have been able to show that coherence of the non-f-atom-sublattice is critical for the observed large m^* in CePtSi. This broadens the impact of the same result in CeCu$_2$Si$_2$. Moreover, our χ and magnetization results, coupled with our results for m^*, favor a Kondo resonance model as the more correct picture for understanding the large m^* ground state rather than a magnetic correlation picture. Since, because of the strong sample and orientation dependence of χ, it was not possible to track both γ and χ as a function of doping in CeCu$_2$Si$_2$, our results in CePt$_{1-x}$Ni$_x$Si provide an important aid to distinguishing between possible models for explaining the heavy fermion ground state.

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