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CePtSi: A new heavy-fermion compound

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We find that CePtSi is a new heavy-fermion and coherent dense Kondo-lattice compound with no magnetic or superconducting transition above 70 mK. Measurements of the magnetic contribution to the electrical resistivity, static magnetic susceptibility, and low-temperature heat capacity of CePtSi are reported. This compound has a large value of the low-temperature magnetic susceptibility [$\chi(2.4\text{ K}) = 24.9\times10^{-3}$ cm^3/mol] and, characteristic of heavy-fermion compounds, an enormous coefficient of the electronic specific heat $\gamma\sim800$ mJ/mol K^2.

The low-temperature electronic, magnetic, and physical properties of heavy-fermion and dense Kondo systems have attracted much interest during the past few years.[1,2] In the course of our search for new heavy-fermion compounds, we have found that CePtSi displays the properties of both heavy-fermion and dense Kondo systems. In this paper, we report the temperature dependence of the electrical resistivity, dc magnetic susceptibility, and heat capacity of polycrystalline CePtSi. As determined from ac susceptibility measurements, this compound has no magnetic or superconducting transition above 70 mK. In addition, electrical resistivity measurements on the isostructural LaPtSi have been made.

The equiatomic RPtSi compounds (R=rare earth) crystallize in a tetragonal LaPtSi-type structure with space group $I4_1md$ (Ref. 3). Samples were prepared by arc melting on a water-cooled Cu hearth in 1 atm of ultrahigh-purity argon gas in which a Zr button used as an oxygen getter had been previously arc melted. Weight losses ($<0.02\%$) during arc melting were negligible. Each sample was wrapped in tantalum foil plus zirconium foil, sealed under argon in a quartz tube, and annealed for four days at 1250 °C, followed by a water quench to room temperature. Powder x-ray diffraction patterns with Cu$K\alpha$ radiation indicated that each sample was single phase, with no additional reflections. The lattice parameters of the unit cell were determined from powder x-ray diffraction patterns by the method of least squares using the eight most intense reflections for $2\theta<55°$ and including an internal silicon standard ($a=0.543083$ nm). The lattice parameters $a=0.4202(1)$ nm, $c=1.4484(4)$ nm for CePtSi and $a=0.4250(1)$ nm, $c=1.4520(1)$ nm for LaPtSi were then obtained, in good agreement with the literature.[3]

dc electrical resistivity measurements were made between 2.4 and 300 K using a standard four-probe technique in a system fully automated for temperature stability and data acquisition.[4] The samples were small rectangular parallelpipeds of approximate dimensions $1\times1\times4$ mm^3. Data were taken with the current applied in both directions to eliminate possible thermal effects. All data presented are for the warming curves. Figure 1 displays the temperature dependence of the resistivity of CePtSi, LaPtSi, and the magnetic resistivity ρ_m of CePtSi. The

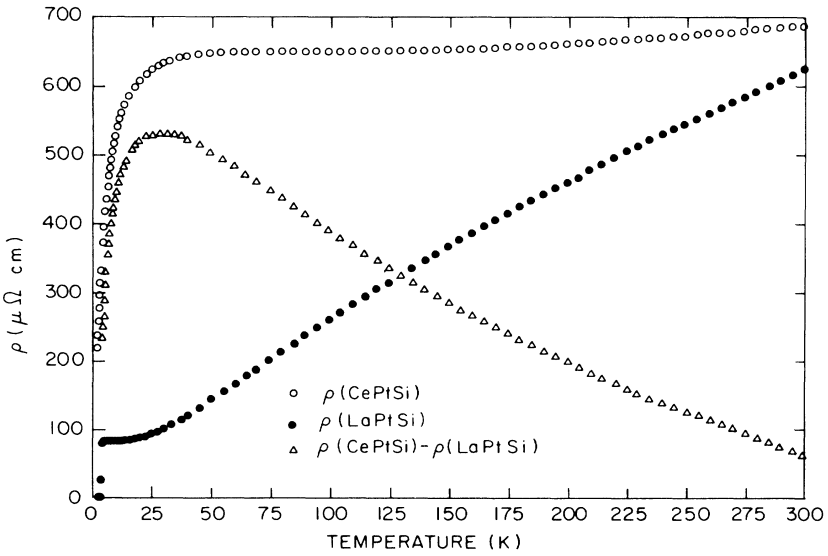

FIG. 1. Resistivity vs temperature of CePtSi, LaPtSi, and the difference between these two compounds from 2.4 to 300 K.

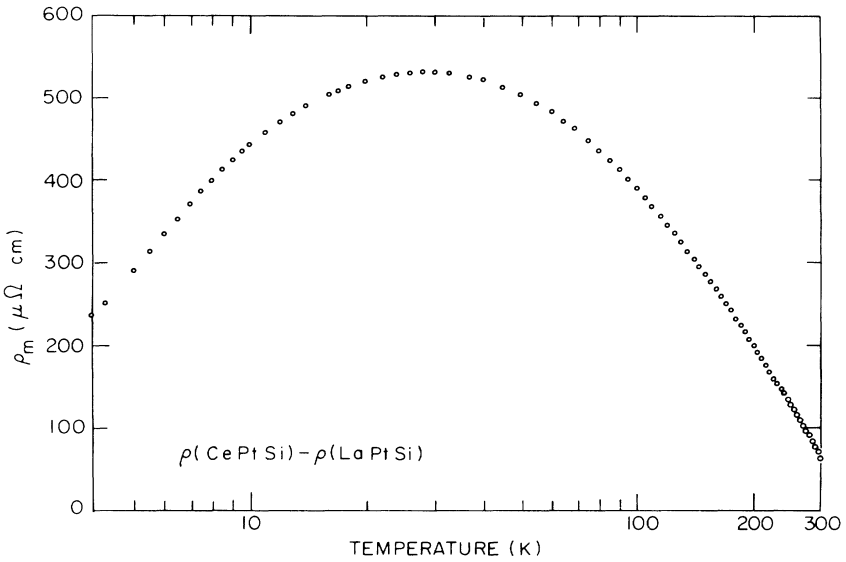

FIG. 2. Magnetic resistivity ρ_m vs $\ln(T)$ of CePtSi between 3.9 and 300 K.

magnetic resistivity was estimated by subtracting the resistivity of isostructural LaPtSi from that of CePtSi. A superconducting transition occurs in LaPtSi at a value of $T_c \sim 3.7$ K, which is slightly higher than the reported value (3.3 K) obtained by ac susceptibility measurements.[5] The CePtSi resistivity curve, which is very similar to that of the heavy fermion UCd_{11} (Ref. 2), shows a rather flat temperature dependence in resistivity above 50 K and falls precipitously below 20 K. The magnetic contribution to the resistivity ρ_m increases to a maximum value at 30 K as temperature is lowered from room temperature. Upon further cooling, ρ_m decreases rapidly below 20 K. This decrease of ρ_m is attributed to the onset of coherence between Kondo states at Ce sites. The data for ρ_m are plotted as a function of $\ln(T)$ in Fig. 2. A $\ln(T)$ dependence is seen in the high-temperature region, which is one of the characteristic features of dense Kondo systems.

Figure 3 presents the temperature dependence of the inverse dc magnetic susceptibility χ^{-1} for the compound CePtSi measured in a field of 2.0 kOe between 2.4 and 300 K with a commercial SQUID magnetometer.[4] The high-temperature data ($T > 70$ K) can be fitted to a linear Curie-Weiss law with an effective moment of $(2.56 \pm 0.05)\mu_B$/Ce atom, a value sufficiently close to the free Ce^{3+} ion value to preclude intermediate valence, and a paramagnetic Curie temperature of -47 K. This large negative Curie temperature is consistent with the presence of a Kondo effect. The compound CePtSi has a large value of the low-temperature magnetic susceptibility [$\chi(2.4\text{ K}) = 24.9 \times 10^{-3}$ cm^3/mol] in comparison to nor-

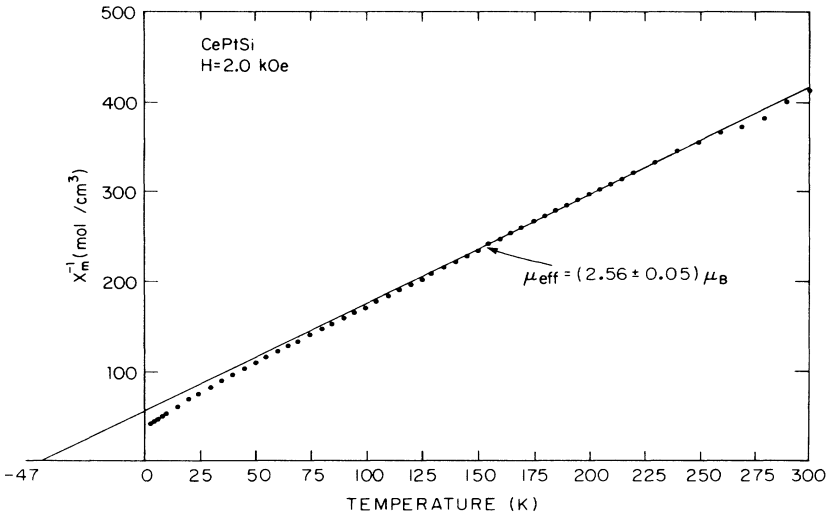

FIG. 3. Inverse molar magnetic susceptibility χ^{-1} vs temperature of CePtSi between 2.4 and 300 K. The straight line represents a least-squares best fit to the data for $T > 70$ K. See text for details.

mal metals which is also typical of heavy-fermion systems.

In order to determine the value of γ, the coefficient of the electronic heat capacity, the specific heat was measured in the temperature range from 1.7 to 30 K with an adiabatic heat-pulse technique. The specific-heat data plotted as C/T against T^2 in Fig. 4 show an upturn below about 11 K. Attempts to fit these data for CePtSi to the equation $C=\gamma T+\beta T^3+\delta T^3 \ln T$, using a least-squares computer fit, fail completely. This is not surprising since only one heavy-fermion compound has specific-heat data that can be fitted by including this additional spin-fluctuation term $\delta T^3 \ln T$; namely, UPt_3 (Refs. 6–8). There are other, nonheavy-fermion systems such as UAl_2 (Refs. 9 and 10) and $TiBe_2$ (Refs. 11 and 12) where the spin-fluctuation term successfully fits the data. For CePtSi, the extrapolation to 0 K (see inset of Fig. 4) yields a value of γ of approximately 800 mJ/mol K^2, which is an enormous value, greater than any other ternary compound that remains nonsuperconducting and nonmagnetic. This extrapolation yields only an estimate for γ. We note that for other Ce-based heavy-fermion compounds that do not exhibit superconductivity or magnetic order such as $CeCu_6$ and $CeAl_3$, C/T attains a maximum at about 0.5 K.[13,14]

From the present study, we conclude that CePtSi is another new heavy-electron and coherent dense Kondo-lattice compound showing neither magnetic order nor superconductivity above 70 mK according to ac susceptibility measurements. To further investigate the heavy-fermion behavior in CePtSi, we have prepared a number of samples in the series $Ce(Pt_xNi_{1-x})Si$. This lengthier study of an isostructural series of compounds will be directed toward the question of the stability of the heavy-fermion state against variations of the lattice parameters (Ce-ligand distances), magnetic susceptibility, and coherent scattering effects as measured by the electrical resistivity.

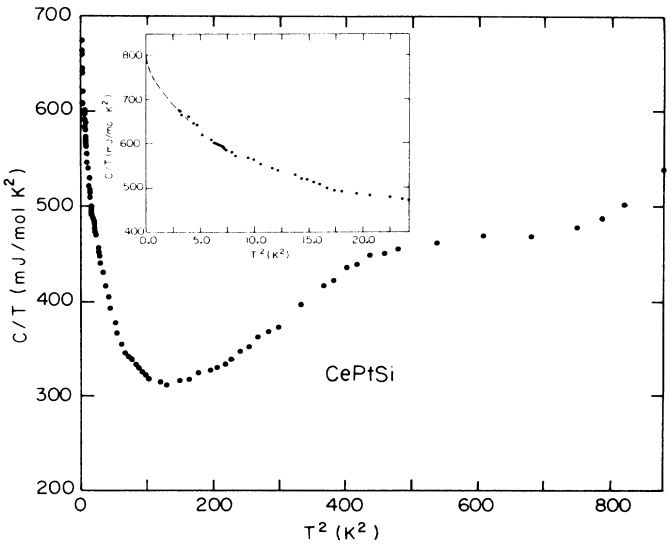

FIG. 4. Specific heat divided by temperature C/T vs T^2 of CePtSi between 1.7 and 30 K. Inset: C/T vs T^2 between 1.7 and 5 K.

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