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Formation and low temperature physics of $CePt_2Si$

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Abstract

$CePt_2Si$ crystallizes in the inverse $CeNiSi_2$-type structure. Magnetic properties are dominated by a mutual interaction of the RKKY interaction, the Kondo effect and crystalline electric field splitting, resulting in long range magnetic order below about 7 K. A slightly enhanced Sommerfeld value $\gamma = 42\,\mathrm{mJ/mol\,K^2}$ and a distinct temperature dependence of the electrical resistivity refers to Kondo interaction in presence of strong crystalline electric field splitting.

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Heavy fermion superconductivity in absence of inversion symmetry, recently discovered in $CePt_2Si$ [1], directed our interest to a systematic exploration of compounds in the Ce–Pt–Si phase diagram. Among other novel ternary compounds, $CePt_2Si$ has been identified and firstly prepared. $CePt_2Si$ was synthesized via argon-arc melting and from X-ray Rietveld refinements was found to crystallize in the inverse $CeNiSi_2$-type ($a = 0.40987(1)$, $b = 1.8032(2)$, $c = 0.41677(3)$ nm; space group Cmcm; $R_F = 0.035$, $R_P = 0.047$). The aim of the present work is a thorough investigation of thermodynamic, magnetic and transport properties of $CePt_2Si$. To define the phonon contributions to the total measured effects, the corresponding quantities have also been investigated for isostructural, non-magnetic $LaPt_2Si$ ($a = 0.41721(4)$, $b = 1.7894(2)$, $c = 0.42378(4)$ nm; $R_F = 0.065$).

Fig. 1 shows the temperature dependent magnetic susceptibility χ plotted as χ^{-1} vs. T for $CePt_2Si$ from 2 to 300 K. Above about 50 K a Curie Weiss like behaviour indicates a simple paramagnetic state. A least squares fit to the modified Curie Weiss law, i.e., $\chi = \chi_0 + C/(T - \theta_p)$ yields an effective moment $\mu_{\mathrm{eff}} = 2.32\,\mu_B$ and a paramagnetic Curie temperature $\theta_p = -47$ K. The effective magnetic moment is close to the theoretical value associated with the Ce^{3+} state, while the slight curvature of the inverse magnetic susceptibility observed below 50 K is attributed to crystal electric field (CEF) effects. A distinct upturn of $1/\chi(T)$ below about 7 K refers to the onset of long range magnetic order, of, presumably, an antiferromagnetic type. This would be in accordance to the negative paramagnetic Curie temperature, indicating antiferromagnetic interactions between conduction electrons and the almost localized 4f electrons. A closer inspection of the low temperature range (see inset, Fig. 1), reveals two consecutive phase transitions at $T_{m1} \approx 7$ K and $T_{m2} \approx 4$ K, respectively. Two magnetic phase transitions at about the same temperatures have been found recently in $CePt_3B$ [2].

The temperature dependent specific heat C_p of $CePt_2Si$ is shown in Fig. 2 together with the non-magnetic isostructural reference compound $LaPt_2Si$. The latter defines the

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phonon contribution and is characterized by a Sommerfeld value $\gamma = 5.5\,\mathrm{mJ/mol\,K^2}$ and a Debye temperature $\theta_D = 225\,\mathrm{K}$. Heat capacity at zero external fields also evidences two successive phase transitions, at 6.6 and 5.6 K, respectively. The latter transition, however, is efficiently eliminated by external magnetic fields as small as 1 T. Isothermal magnetization measurements (not shown here), reveal, most likely, antiferromagnetism in both phases, and a metamagnetic transition takes place at 3.5 T at $T = 1.7\,\mathrm{K}$.

In order to qualitatively account for the ordered region of $CePt_2Si$, a model developed by Continentino et al. [3] is applied, considering gapped antiferromagnetic spin waves. A least squares fit reveals for $T \ll T_{m2}$ a spin wave gap $\Delta \approx 4.8\,\mathrm{K}$ together with a Sommerfeld constant $\gamma = 42\,\mathrm{mJ/mol\,K^2}$ (solid line, Fig. 2).

The magnetic entropy associated with both phase transitions attains about $4.8\,\mathrm{J/mol \cdot K}$ at $T = T_{m1}$, which is about 15% below the entropy release of a magnetically ordered state in an unperturbed crystal field ground state doublet. R ln 2 is reached at about 16 K. This discrepancy is considered as a consequence of the Kondo effect, screening, at least partly, the Ce moments and spreading entropy to higher temperatures. In terms of a Bethe ansatz calculation [4], the Kondo temperature follows from these entropy data as $T_K \approx 2\,\mathrm{K}$. Since $T_{m1} \gg T_K$, Kondo type

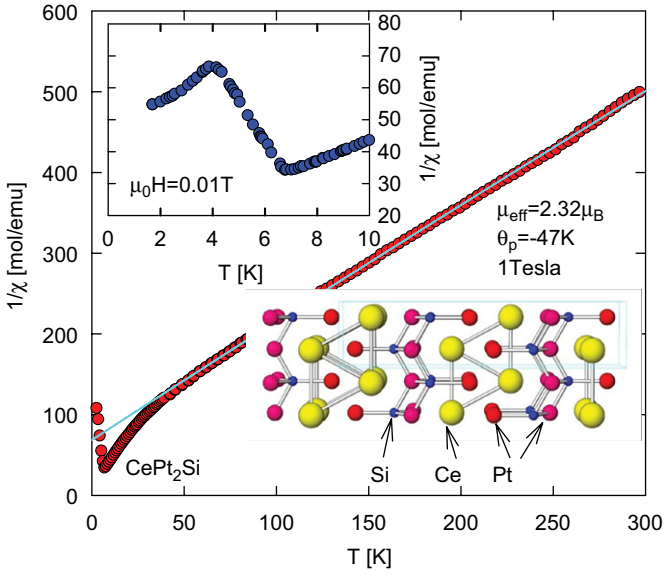

Fig. 1. (a): Temperature dependent magnetic susceptibility χ of $CePt_2Si$ plotted as $1/\chi$ vs. T. The solid line is a least squares fit according to the modified CW-law. The inset show low temperature details. The lower panel sketches the crystallographic unit cell of $CePt_2Si$.

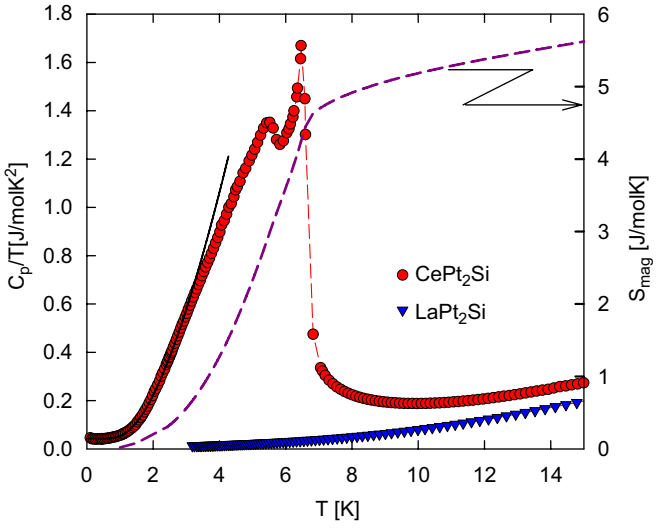

Fig. 2. Temperature dependent specific heat C_p of $CePt_2Si$ and $LaPt_2Si$ plotted as C_p/T vs. T (left axis). The solid line is a least squares fit using the model Ref. [3]. The magnetic entropy associated with $CePt_2Si$ is shown as dashed line (right axis).

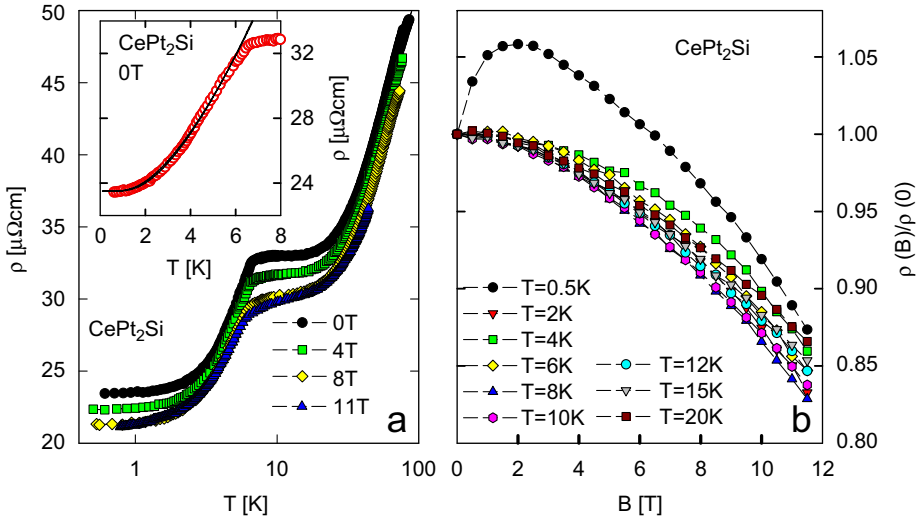

Fig. 3. (a) Temperature dependent electrical resistivity ρ of $CePt_2Si$ measured at various externally applied magnetic fields. The inset shows low temperature features of $\rho(T)$ and the solid line is a least squares fit using the model Ref. [3]. (b) Isothermal magnetoresistance of $CePt_2Si$.

interaction appears to be weak in comparison to the RKKY interaction strength, placing this compound far left in Doniach's phase diagram of Kondo lattices. As a further consequence, the ordered moments should be almost unaffected and basically governed by the crystal field level scheme.

Fig. 3(a) displays the temperature dependent electrical resistivity ρ of $CePt_2Si$ for various fields. A distinct kink in $\rho(T)$ around 7 K indicates the onset of long range magnetic order, which softens if magnetic fields are applied.

Employing the above model [3] allows a description of $\rho(T)$ well below T_m. A least squares fit (solid line, inset Fig. 3) yields a gap of 5.8 K, in fair agreement with the specific heat analysis. Isothermal magnetoresistance data are shown in Fig. 3(b). Data taken at 500 mK is initially positive, and exhibiting a maximum around 2 T, referring to a critical field, where the magnetic structure reorientates. Above that field, magnetoresistance diminishes, referring to a ferromagnetic-like arrangement of the magnetic moments and a quenching of spin fluctuations as the field strength further increases. Above T_{m1}, $\rho(B)/\rho(0)$ decreases and the s-shaped dependence reminds to Kondo type interaction.

In conclusion, the new ternary Ce compound, $CePt_2Si$ has been synthesized and structurally characterized. The almost localized Ce-4f moments order antiferromagnetically below $T_{m1} = 6.6\,K$ followed by a spin-reorientation at $T_{m2} = 5.6\,K$. The spin wave structure is gapped with $\Delta \approx 5\,K$. Kondo type interactions are responsible for a moderately high Sommerfeld value $\gamma = 42\,mJ/mol\,K^2$.

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References

[1] E. Bauer, et al. Phys. Rev. Lett. 92 (2004) 027003.
[2] R. Lackner, et al., J. Phys.: Condens. Matter 17 (2005) S905.
[3] M.A. Continentino, et al., Phys. Rev. B 64 (2001) 012404.
[4] H.U. Desgranges, K.D. Schotte, Phys. Lett. A 91 (1982) 240.