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Thermal expansion and magnetostriction of $CePt_2Si_2$

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We have measured the coefficients of linear thermal expansion of a single-crystalline sample of the tetragonal Kondo-lattice compound $CePt_2Si_2$ over a wide temperature range ($0.3 < T < 220$ K). The coefficient of volume expansion exhibits two broad anomalies centered at 70 and 180 K. Magnetostriction data taken at 0.4 K ($B \parallel [110]$), confirm the presence of a metamagnetic-like transition at 2.6 T.

In the ternary compound $CePt_2Si_2$ anomalies observed in the electrical resistivity [1], the magnetic susceptibility [1] and the specific heat [1,2], indicate the presence of three distinct regimes. For temperatures above $T_K \approx 60$ K, a single-ion (Ce^{3+}) Kondo behaviour is observed. For 4 K $< T < T_K$, electron correlations build up a Fermi-liquid state. Below 4 K, yet another regime, attributed to the formation of the coherent Kondo-lattice, is attained. Inelastic neutron-scattering data [3] reveal a broad quasi-elastic response yielding a two times larger value for T_K (130 K). The γ-value of 80 mJ/(mol K^2) places $CePt_2Si_2$ in the intermediate regime, between Kondo-compounds with a high T_K and the heavy-fermion compounds. The crystalline electric field (tetragonal crystal structure of the $CaBe_2Ge_2$-type) splits the $J = 5/2$ multiplet into 3 doublets. The energy scheme equals 0–194–415 K, as deduced from the inelastic peaks in the neutron spectra [3]. Specific-heat data yield a first doublet–doublet splitting of about 240 K [2]. The electronic and magnetic properties are strongly anisotropic. Below ~ 4 K, a metamagnetic-like transition is observed in the magnetization [4,5], for a field of ~ 2 T directed in the basal plane (easy plane for magnetization). In analogy with the heavy-fermion compound $CeRu_2Si_2$, where a metamagnetic-like transition occurs at 8 T in the liquid helium temperature range [6], it has been suggested that antiferromagnetic interactions dominate the low-temperature properties in $CePt_2Si_2$, and thus a competition between the RKKY interaction and the Kondo-effect takes place.

In order to shed more light on the low-temperature properties of $CePt_2Si_2$, we report on an investigation of the magnetovolume effects. The coefficients of linear thermal expansion along ($\alpha_\parallel$) and perpendicular ($\alpha_\perp$) to the tetragonal axis, have been measured on a single-crystalline sample over a large temperature range ($0.3 < T < 220$ K). The magnetostriction ($B < 8$ T) has been measured along and perpendicular to the field ($B \parallel [110]$) at temperatures of 0.4, 1.4 and 4.2 K.

The single-crystalline sample was shaped by means of sparc-erosion. Planparallel surfaces were obtained perpendicular to the [110] and [001] direction. The sample was mounted in a dilatation cell machined of OFHC copper [7]. The coefficient of linear thermal expansion, $\alpha = L^{-1}\mathrm{d}L/\mathrm{d}T$(with $L \approx 3$ mm), was measured using a sensitive three-terminal capacitance technique, with a detection limit of 0.1 Å. Data below 4.2 K were taken in a ^{3}He cryostat, and data there above in a bath cryostat. The linear magnetostriction, $\lambda(B) = \Delta L/L$, was measured by recording the length change while slowly sweeping the field. During field sweeps the temperature was kept stable by regulating on a field insensitive RuO_2 thermometer.

The experimental results for $\alpha_\parallel$ and $\alpha_\perp$ are shown in fig. 1, where we also show the coefficient of volume expansion, $\alpha_v = \alpha_\parallel + 2\alpha_\perp$ (we have plotted $\alpha_v/3$). The temperature region below 15 K is detailed in fig. 2. The expansion is strongly anisotropic (above 2 K). The volume effect receives its main contribution from the basal plane expansion. The steep rise at low temperatures is followed by two weak maxima, indicating con-

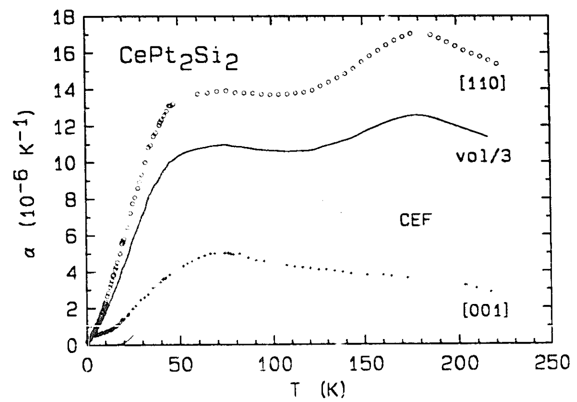

Fig. 1. The coefficient of linear thermal expansion of single-crystalline $CePt_2Si_2$, along (+) and perpendicular (○) to the tetragonal axis. The solid line represents $\alpha_v/3$ (the phonon contribution is not subtracted). For comparison, the contribution (Schottky anomaly) of the crystalline electric field with excited doublets at 194 and 415 K [3] is shown (dotted line with label CEF, α_{max} is normalized to 10).

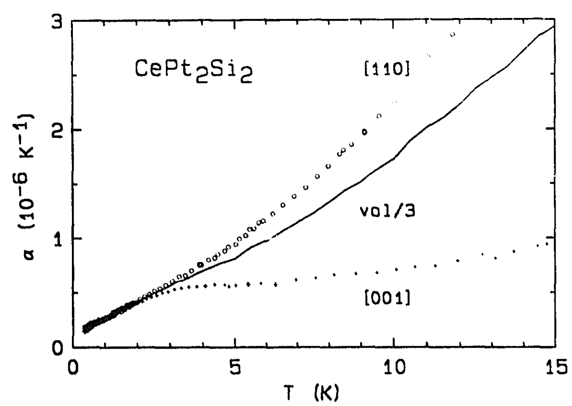

Fig. 2. The coefficient of linear thermal expansion versus temperature ($T < 15$ K) for single-crystalline $CePt_2Si_2$, along (+) and perpendicular (○) to the tetragonal axis. The solid line represents $\alpha_v/3$.

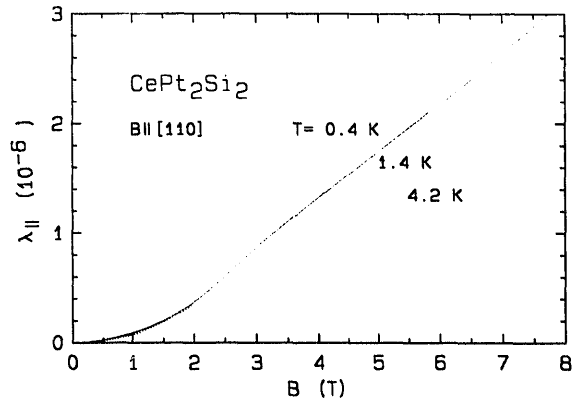

Fig. 3. The magnetostriction, $\lambda_{\parallel} = \Delta L/L$, of $CePt_2Si_2$ for an elongation direction along the applied magnetic field, $B \parallel [110]$, at temperatures as indicated.

tributions centered at 70 and 180 K. The contribution from the crystalline electric field, calculated with the energy splittings as deduced from the neutron data, yields only one broad maximum at 85 K as shown in fig. 1 (the two doublet–doublet splittings do not appear as a separate maxima). Also the susceptibility and resistivity do not exhibit any anomaly at 180 K [1]. Therefore, we suggest that the anomaly at 180 K is related to an anomalous phonon mode, as supported by the neutron-scattering data [3] that reveal a large contribution of phonons in the range 10–20 meV. Thermal expansion data on the non-f-electron analog system $LaPt_2Si_2$ are not yet available, hampering a thorough analysis. The data in fig. 2 confirm the presence of an additional anomaly below ~ 5 K, i.e. a small bump centered around 3–4 K. The effective Grüneisen parameter, $\Gamma_{eff}(T) = V_m\alpha_v(T)/\kappa_c(T)$, increases rapidly with decreasing temperature below ~ 20 K. The value for $\kappa\Gamma$ amounts to about 30 for the low-temperature contribution (the compressibility κ is not known, but is of the order of 1 $Mbar^{-1}$). Such large values are commonly observed in heavy-fermion systems [8].

The low-temperature magnetostriction along a field in the basal plane ($\lambda_{\parallel}$) is shown in fig. 3. An anomalous behaviour is clearly visible at 0.4 K, confirming the metamagnetic-like behaviour observed previously in the magnetization curves [5]. The inflexion point in the $\lambda(B)$ versus B curve at 0.4 K lies at 2.7 T. Data were taken with increasing and decreasing field. No hysteresis was found within the experimental accuracy. The metamagnetic-like transition also turned up in the data (not shown) for an elongation direction perpendicular to the field ($\lambda_{\perp}$). However, in that case a rather large hysteresis was observed. Note that hysteresis effects at the metamagnetic transition in $CeRu_2Si_2$ have not been observed.

In summary, our magneto-volume study supports the anomalous behaviour of $CePt_2Si_2$, previously observed in the magnetic, transport and thermodynamic properties. The low-temperature metamagnetic-like behaviour is confirmed by magnetostriction data at 0.4 K. The discovered anomaly at 180 K in the coefficient of volume expansion asks for a detailed investigation of the phonon spectrum.

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