Thermal expansion of CeCu$_{6-x}$Au$_x$

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Abstract

CeCu$_{6-x}$Au$_x$ orders antiferromagnetically for $x > 0.1$. The ordering wave vector changes drastically between $x = 0.4$ and 0.5, while the Néel temperature $T_N(x)$ varies linearly between $x = 0.1$ and 1.0. The linear thermal expansion coefficient $\alpha$ shows for $x = 0.3$ a positive jump $\Delta \alpha$, while $\Delta \alpha_b$ and $\Delta \alpha_c < 0$. When increasing $x$ to $x = 0.5$, $\Delta \alpha_a$ and $\Delta \alpha_b$ change sign, apparently reflecting the underlying change of the magnetic ordering wave vector.

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While CeCu$_6$ is a heavy-fermion system without magnetic order, except perhaps at ultra-low temperatures ($T \sim 3$ mK), CeCu$_{6-x}$Au$_x$ is an incommensurate antiferromagnet for $x > x_c \approx 0.1$, with the Néel temperature $T_N$ varying linearly in the range $0.1 < x \leq 1$ [1]. The latter sample, i.e. CeCu$_{5.5}$Au with $T_N = 22$ K, is in fact a stoichiometric compound with the Au atoms sitting exclusively at the Cu(2) site of the CeCu$_6$ structure [2]. For $x > 1$ $T_N$ decreases again. The ordering wave vectors determined from elastic neutron scattering reside within the reciprocal $a^*e^*$ plane, with however a drastic change between $x = 0.4$ and 0.5 [3]. (Here we use the orthonormatic notation to denote the lattice vectors, neglecting the small monoclinic distortion by $\sim 1.5^\circ$ for CeCu$_6$, which is rapidly suppressed with increasing $x$ and vanishes at $x = 0.14$ [4].) For $x = 0.5$ and 1 the ordering wave vector $\mathbf{Q}$ lies on the $a^*$-axis, i.e. $\mathbf{Q} = (0.590 0 0)$ for $x = 0.5$ and $\mathbf{Q} = (0.560 0 0)$ for $x = 1.0$. However, for $x < 0.5$, $\mathbf{Q}$ is distinctly different: $\mathbf{Q} = (0.625 0.275)$ for $x = 0.2$ and $\mathbf{Q} = (0.62 0.253)$ for $x = 0.3$. A similar $\mathbf{Q}$ vector was found for $x = 0.4$ [5]. We limit the discussion to long-range order with resolution-limited Bragg peaks and do not consider short-range order effects [3]. The drastic change of $\mathbf{Q}$ between $x = 0.4$ and 0.5 (see inset of Fig. 1) contrasts with the smooth linear evolution of $T_N(x)$ and presents a major puzzle. Furthermore, while hydrostatic pressure leads to a decrease of $T_N$ for all $x$ [1,6], uniaxial pressure measurements performed on $x = 0.2$ single crystals indicate a decrease of $T_N$ for uniaxial pressure parallel to the $b$ and $e$ axes but, surprisingly, an increase for uniaxial pressure parallel to the $a$-axis [7,8]. Here we report thermal expansion measurements to shed some light on these issues.

The thermal expansion coefficient $\alpha_i (i = a, b, c)$ was measured between 0.35 and 10 K with a parallel-plane capacitance dilatometer in a $^3$He cryostat. The absolute error in $\alpha_i$ is about $3 \times 10^{-7}$ K$^{-1}$, which is mainly attributed to small differences in the effective area of the capacitor plates between different runs. The error in the volume expansion $\alpha_V = \alpha_a + \alpha_b + \alpha_c$ amounts to $5 \times 10^{-7}$ K$^{-1}$.

Figs. 1 and 2 show the thermal expansion coefficients $\alpha_i$ versus $T$ for $x = 0.3$ and $x = 0.5$, respectively. The discontinuities $\Delta \alpha_i$ at $T_N = 0.5$ and 1 K, respectively, are clearly visible, although the lower measuring temperature limit of 0.35 K makes the determination of the discontinuity for $x = 0.3$ somewhat uncertain. The main...
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