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Thermal Expansion of a $La_{1.87}Sr_{0.13}CuO_4$ Single Crystal at T_c in High Magnetic Fields

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We present high-resolution dilatometry measurements of a $La_{1.87}Sr_{0.13}CuO_4$-single crystal parallel and perpendicular to the CuO_2-planes in magnetic fields up to 14 Tesla. We find a strong suppression of the thermal expansion anomalies for magnetic fields parallel to the c-axis. In contrast, a magnetic field perpendicular to the c-axis affects the anomalies only weakly.

The thermal expansion α of $La_{1.87}Sr_{0.13}CuO_4$ (LSCO) shows pronounced and anisotropic anomalies at T_c in zero magnetic field [1]. From a study of the field dependence of these anomalies one may obtain information on the suppression of the superconducting transition in a magnetic field and on the influence of superconducting fluctuations. Moreover, it should be possible to decouple the superconducting anomalies from additional structural anomalies, which are suggested to occur at T_c in high temperature superconductors (HTSC) [2].

In this paper we present the first study of the field dependence (up to 14 Tesla) of the thermal expansion on a single crystal of LSCO.

The single crystal used in our experiments was grown by the traveling solvent floating zone method [3]. The superconducting transition temperature in zero field is $T_c(0) \simeq 32.5(5)$ K as determined by specific heat measurement [1]. The crystal surfaces are parallel to (001) or (110) planes in the orthorhombic notation. Thermal expansion $\alpha_{a,b}$ along the ab-direction and α_c along the c-direction was measured in high magnetic fields with a capacitance dilatometer [4]. We emphasize that the magnetic field was always applied well above $T_c(0)$ to avoid magnetostrictive effects, which are known to be large in HTSC-single crystals [5].

In Fig. 1 we show $\alpha_{a,b}$ and α_c as a function of temperature measured for the magnetic field in the c-direction. One observes at first glance that the zero field anomalies at T_c are rapidly suppressed with increasing magnetic field. Apparently, from α_c one finds that there are no anomalies for $B > 7T$. Note that the upper critical field for $B \parallel c$ is order $H_{c2} \approx 30T$ [6].

Anomalies $\delta\alpha$ can be obtained from the data of fig.1 by subtracting a "normal" contribution extrapolated from the behavior of α at temperatures far below and above T_c. Notably, the "normal" contribution obtained in this way aggrees well with the measured α_c for $B > 7T$, which indicates that the anomalies of α_c are indeed completly suppressed in high fields. (Note that $\delta\alpha$ as defined above is not the mean field jump of α at T_c.)

The anomalies $\delta\alpha_{a,b}$ are shown in fig.2. In the inset of fig.2 we show the field dependence of $\Delta L/L = \int \delta\alpha dT$ normalized to its maximum value as extracted from α_c and $\alpha_{a,b}$. $\Delta L/L$ extrapolates to zero for $B \approx 7T$.

We can obtain $T_c(B)$ from $\delta\alpha$ by an area conserving construction. We find that T_c is only weakly suppressed with increasing field (for $B = 4T$ we find a suppression of about 4K).

We have also performed measurements of $\alpha_{a,b}$ for magnetic fields along the ab-direction and for magnetic fields tilted with respect to the crystal axes. These results will be presented in another publication. We note here that $\alpha_{a,b}$ measured for $H = 14T \parallel ab$ is equal to $\alpha_{a,b}$ measured for $H = 0.5T \parallel c$. From this we can extract the anisotropy parameter $\Gamma = \xi_{a,b}/\xi_c \approx 28$. For ma-

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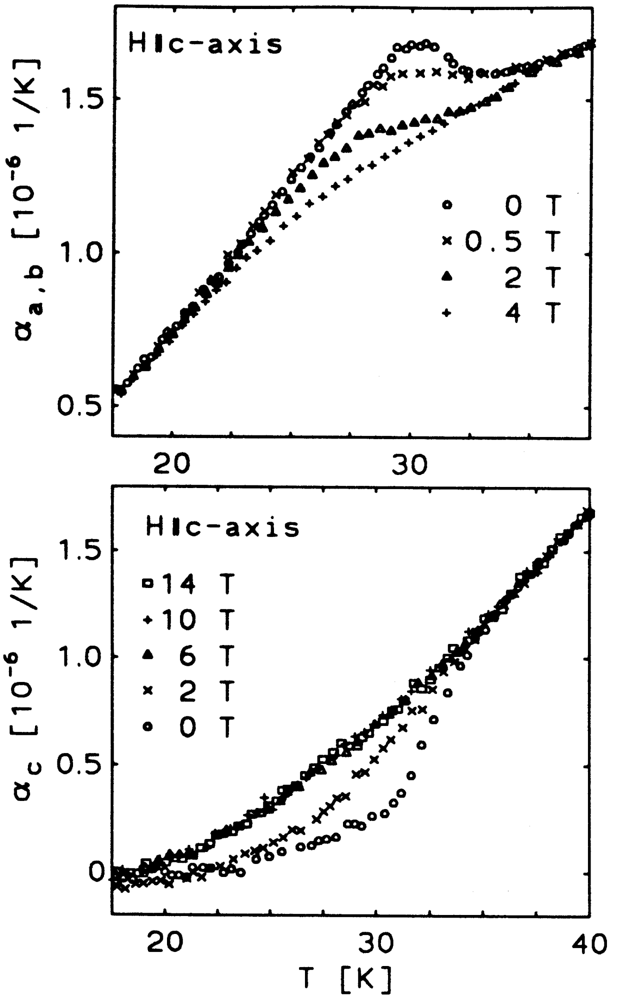

Figure 1. Thermal expansion vs. temperature along a,b-axis (upper panel) and c-axis (lower panel) in various magnetic fields.

gnetic fields tilted with respect to the crystal axes the magnetic field component perpendicular to the CuO_2-planes dominates the anomalies of α.

The most striking result of our experiments is the rapid suppression of $\delta\alpha$ with increasing magnetic field and the complete absence of anomalies for $B > 7T$. From the Ehrenfest relation $\Delta\alpha_i \propto \Delta c_p(dT_c/dp_i)$ this can be related to a strong suppression of the specific heat anomaly Δc_p with increasing magnetic field. Such behavior is indeed found in the specific heat of Y-Ba-Cu-O and Bi-based superconductors for $B \parallel c$ [7].

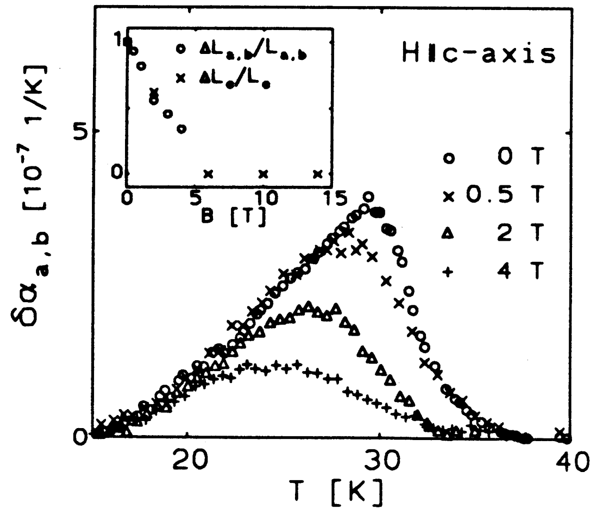

Figure 2. $\delta\alpha_{a,b}$ vs. temperature. Inset: $\Delta L/L$ as extracted from $\delta\alpha_{a,b}$ (open circles) and $\delta\alpha_c$ (crosses) vs. magnetic field. (see text.)

However, the suppression of Δc_p is not complete even in the largest fields studied. Therefore, one may speculate on an additional cause for the complete suppression of $\delta\alpha$, e.g. a strong field dependence of dT_c/dp. High-field measurements of the specific heat of LSCO are in progress in order to check this point.

We finally point out that the suppression of $\delta\alpha$ with increasing magnetic field excludes the existence of an additional structural transition at T_c [2], since the latter should be independent of the magnetic field.

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