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Local magnetic relaxation in $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$ crystals

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Local magnetic measurements in $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$ crystals show a 'fishtail' anomaly in the magnetization curves together with anomalous relaxation behavior similar to that measured in $YBa_2Cu_3O_{7-x}$ crystals, suggesting a universal flux dynamics in the field range of the fishtail peak.

Magnetic relaxation in high-T_c superconductors is a subject of intensive study [1]. Recently, **local** magnetic measurements in $YBa_2Cu_3O_{7-x}$ (YBCO) crystals [2] revealed anomalous relaxation behavior in the same field range where the 'fishtail' is observed. In this article we present local magnetic relaxation data in $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$ (NCCO) crystal, demonstrating similar features.

Measurements were performed on a $1.2\times0.35\times0.02$ mm^3 NCCO crystal ($T_c \approx 23$ K), using an array of 11 GaAs/AlGaAs Hall sensors with 10×10 μm^2 active area and sensitivity better than 0.1 G. The probes detect the component B_z of the field normal to the surface of the crystal. Temperature stability and resolution were better then 0.01 K. After zero-field-cooling (zfc) the sample from above T_c to the measurement temperature T we measured the full hysteresis loops for all the probes with field parallel to the c-axis of the crystal. The first field for full penetration H^* was measured directly by the probe at the center of the sample. After repeating the zfc process, a dc field H was applied parallel to the c-axis and the local induction B_z was measured at different locations as a function of time. These relaxation measurements were repeated after the field was increased by a step $\Delta H > 2H^*$ up to the irreversibility field H_{irr}. The inset to Figure 1 shows typical hysteresis loops, $m_z = B_z - H$ *vs.* H at T = 13 K for probes located at 13, 33, 53, and 73 μm

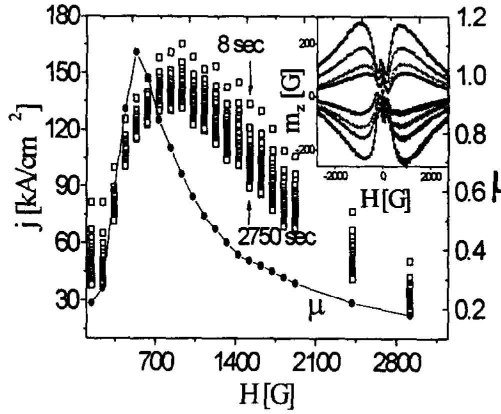

Figure 1. Field dependence of the current j at different times (squares) and of the exponent μ (circles). Inset: Magnetization loops for different probes.

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from the center of the crystal. Each probe exhibits a clear fishtail behavior with a maximum width at field $H_p \approx 900$ G. The width of the loop is largest at the center of the crystal and decreases towards the edges, as expected from the critical-state model [3].

In Figure 1 we show the time evolution of the current between $t_1 = 8$ s and $t_2 = 2750$ s, as a function of the applied field. The large relative relaxation of the current, $\Delta j/j$, during the time window of the measurement implies that the dynamics strongly affects the shape of j(B) and the location of the peak. Knowledge of the time and spatial induction distributions enables direct, model independent determination of the activation energy U(B, j) associated with the flux creep [4]: By using the equation for flux motion, $\partial B/\partial t = -\nabla\times(B\times v)$, where the effective vortex velocity v is proportional to $exp(-U/kT)$, U is derived directly from the raw data. Typical U *vs.* j data, at 13 K and fields between 240 G and 2900 G, are shown in Figure 2.

In order to quantify the dependence of U on j we use the prediction of the collective creep theory [5] (assuming $j \ll j_c$):

$$U(B, j) = U_c(B)(j_c/j)^{\mu} \qquad (1)$$

where the positive critical exponent μ depends on the specific pinning regime. The

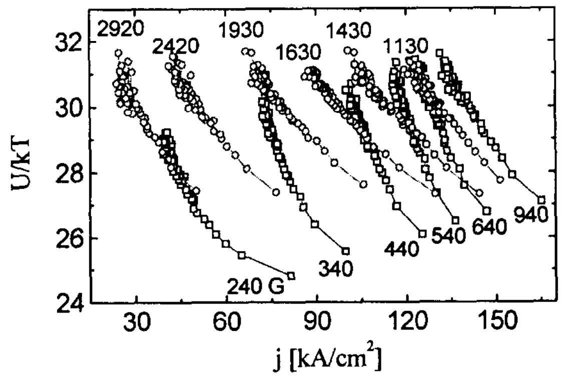

Figure 2. U(j) dependence for fields $H < H_p$ (squares) and for fields $H > H_p$ (circles).

circles in Figure 1 describe the field dependence of the exponent μ obtained by fitting Eq. (1) to the experimental data. At low fields μ changes from about 0.2 to the highest value of more than 1 in agreement with the collective creep theory - these values correspond to the crossover from the single vortex creep regime to the bundle regime [5]. However, at higher fields μ decreases down to values less than 0.2 and it would imply an inconceivable crossover to a single vortex regime (μ = 1/7) which is expected only for low fields and high values of j. Thus, the μ values at high fields are inconsistent with the collective creep theory. As argued by Abulafia *et al.* in their measurements of YBCO [2], it is possible to explain this behavior as indicating an elastic-to-plastic creep crossover.

As compared to YBCO, NCCO exhibits smaller T_c, larger anisotropy [6], and lower field range for the fishtail anomaly. Moreover, the origin of the fishtail in NCCO and YBCO may be different [7]. Yet, in both cases, similar anomaly in the relaxation is observed in the field range of the fishtail. The connection between these two phenomena requires further investigation.

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