



Flux pinning by twin planes in Nd-123 and Y-123 single crystals

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Abstract

The pinning by twin planes and an isotropic pinning disorder was investigated on single crystals of $\text{NdBa}_2\text{Cu}_3\text{O}_{7-\delta}$ and $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ studying the angular dependence of total magnetic moment measured quasistatically by means of SQUID and dynamically by means of a vibrating sample magnetometer. The field dependence of the normalized relaxation rate of the vortex system pinned by twin planes, and by a random isotropic pinning disorder was determined. The qualitative difference of the two field profiles is clearly reflected by the shapes of the corresponding magnetic hysteresis loops. Material aspects of the pinning and the effect of the measurement method are discussed. © 2000 Elsevier Science B.V. All rights reserved.

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In the previous experiments on twinned $\text{NdBa}_2\text{Cu}_3\text{O}_{7-\delta}$ samples the magnetic hysteresis loops measured at different angles θ between c -axis and the external field exhibited at low temperatures a shoulder on the low-field side of the fishtail peak. To distinguish between the effect of twins and the potential contribution to pinning from Nd-Ba clusters [1,2], we compared the magnetic behavior of $\text{NdBa}_2\text{Cu}_3\text{O}_{7-\delta}$ ($0.6 \times 0.5 \times 0.015 \text{ mm}^3$) and $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ ($2 \times 1.8 \times 0.03 \text{ mm}^3$) single crystals (further referred as Nd and Y sample, respectively). The twin structure and the configuration of both experiments was similar. It consisted of a few twin domains with planes oriented perpendicular to each other as shown in Fig. 1 in Ref. [3]. The DC field was rotated within the plane perpendicular to the axis, lying in the sample plane and declined by $\approx 17^\circ$ from one of the principal twin plane directions, as also indicated in the above-mentioned figure. Due to large dimensions of the Y sample we used a less sensitive method of vibrating sample magnetometer (VSM). This experimental method

enabled us to investigate also the dynamics of pinning and depinning processes. The plots of the c -axis component of magnetic moment as a function of the c -axis component of magnetic field measured with three different field sweep rates at 60 K are shown in Fig. 1(a) for two limiting cases, $\theta = -20^\circ$ and $\theta = 0^\circ$. In contrast to our previous SQUID experiments on Nd samples, we observed a significant sinking of the fishtail minimum with increasing $|\theta|$. A similar behavior was, however, observed also on twin-free single crystals of $\text{DyBa}_2\text{Cu}_3\text{O}_{7-\delta}$ [4]. It is therefore impossible to assign this effect to twin planes alone. Also field sweep has a different effect on the MHLs measured at different angles: The sensitivity of the magnetic moment to field sweep increases with increasing $|\theta|$. Quantitatively this behavior can be described in terms of normalized relaxation rate, $Q = \partial \ln(M) / \partial \ln(dB/dt)$, Fig. 1(b). We see that Q varies with B at $\theta = 0^\circ$ (twins) much less than at a higher $|\theta| \approx 20^\circ$ (point-like pinning sites). A detailed comparison of both figures gives also a strong support to the arguments of Perkins et al. [5], who related Q to the logarithmic susceptibility $\partial \ln(M) / \partial \ln(B)$ of the MHL. We see that differently shaped curves of $Q(B)$ at $\theta = -20^\circ$ and $\theta = 0^\circ$ have their extremes always close to inflection points of the corresponding MHL.

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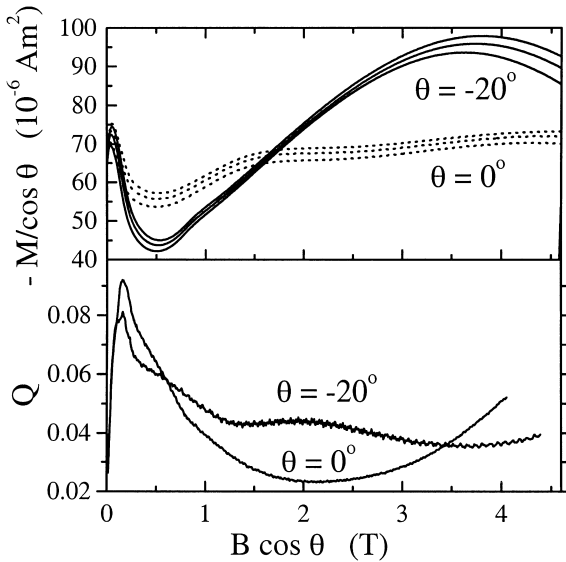


Fig. 1. (a) MHLs measured on the Y single crystal by VSM with field sweep rates of 10, 6.6, and 3.3 mT/s (top to bottom). B was oriented along $\theta = -20^\circ$, and $\theta = 0^\circ$. Temperature $T = 60$ K. (b) The corresponding normalized relaxation rates, $Q = \partial \ln(M)/\partial \ln(dB/dt)$.

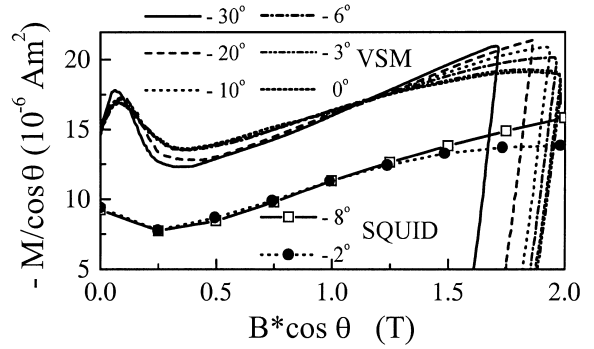


Fig. 2. MHLs measured on the Nd single crystal by VSM with the field sweep rate of 28 mT/s. B was oriented at different angles between $\theta = -30^\circ$ and $\theta = 0^\circ$; $T = 60$ K. For comparison also SQUID data are shown.

No shoulder on the low-field slope of the fishtail peak was observed in the Y sample at temperatures down to 30 K. This speaks in favour of the pinning sites specific to Nd-based materials that might be responsible for the shoulder observed in the latter samples.

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To check the the low-field behavior of the Nd sample under the field sweep regime, we tested this sample by means of VSM, too. In Fig. 2 we present the scaled ascending branches of the MHLs measured at different angles θ (the nominal field sweep rate was always 28 mT/s). For comparison, we also show the curves measured previously by SQUID. The inspection of the figure enables the following conclusions: First, a remarkable difference is apparent between the magnetic moment values measured by VSM and SQUID. It is due to the significantly relaxed state of the sample in the course of SQUID measurements. Second, we see a similar deepening of the fishtail minimum with increasing $|\theta|$ as in the Y sample, only less pronounced. Third, the well aligned field-reversal legs of the MHLs give evidence that the $\cos\theta$ scaling is a good approximation.