

## COMPETITION BETWEEN PINNING ON CORRELATED AND UNCORRELATED DISORDER IN Nd-123 SINGLE CRYSTAL

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### ABSTRACT

On a  $\text{NdBa}_2\text{Cu}_3\text{O}_{7.8}$  single crystal at temperatures below 75 K a competition is observed between pinning on a point-like non-correlated disorder and a two-dimensional structure of twin boundaries. The former pinning regime prevails at external fields declined more than  $\approx 4^\circ$  from the plane of the twin structure. In this case, a clear fishtail shape appears on  $j_c(B)$  curve. At applied fields sufficiently close to the plane of twin boundaries, vortices become locked-in at the twin structure, which significantly reduces  $j_c$  at the fields around the fishtail maximum. Consequences of this behaviour are discussed.

### INTRODUCTION

Single crystals of  $\text{NdBa}_2\text{Cu}_3\text{O}_{7.8}$  exhibit high values of  $T_c$  accompanied by relatively high critical current densities at high fields. This makes this material particularly interesting for applications. A nontrivial shape often complicates the analysis of magnetic hysteresis loops (MHLs) in these samples. The central peak is separated from the high-field fishtail maximum by an intermediate peak appearing at about 2 T. This peak is practically independent of temperature. In the present contribution, we report on the angular dependence of MHLs measured at different temperatures and discuss the scaling properties of the high-field part of the MHL.

### RESULTS AND DISCUSSION

MHLs were measured by means of a commercial SQUID magnetometer (Quantum Design MPMS7 equipped with a horizontal rotator) on  $\text{NdBa}_2\text{Cu}_3\text{O}_{7.8}$  single crystal exhibiting a simple single-domain twin structure [1]. Magnetic data were recorded under different angles  $\theta$  between c-axis and the applied field. Figure 1 shows a typical result: At temperatures below 75 K the MHL exhibits a typical fishtail shape if  $\theta$  differs from zero more than by 10 degrees. When the magnetic field direction comes close to c-axis, the vortices become pinned at twin planes [2-4], which results in a gradual depression of the MHL shape around the fishtail maximum. At  $|\theta| < 4^\circ$ , magnetic flux is fully locked-in at twin boundaries thus causing the critical current density at fields around the fishtail maximum to be nearly field-independent and insensitive to changes of  $\theta$ . However, when  $|\theta|$  exceeds  $4^\circ$ , vortices, or at least parts of them, are released from the twin planes towards the field direction and become pinned by the point-like pinning sites as originally. At these angles, the critical currents at fields around the fishtail maximum become again angle-dependent. The  $j_c(B)$  curves remain somewhat depressed until  $\theta \approx 7^\circ$  where the MHLs recover the fishtail shape again. It seems, however, that part of magnetic flux remains locked within twin structure, which slightly reduces the vortex mobility. As a result, the critical currents are slightly higher at the fields below fishtail maximum than expected for the case of pinning on the isotropic point-like disorder [5]. At the fields well above fishtail peak, the MHL shape is insensitive to details of the actual pinning structure. This indicates that vortex dynamics is in this field range go-

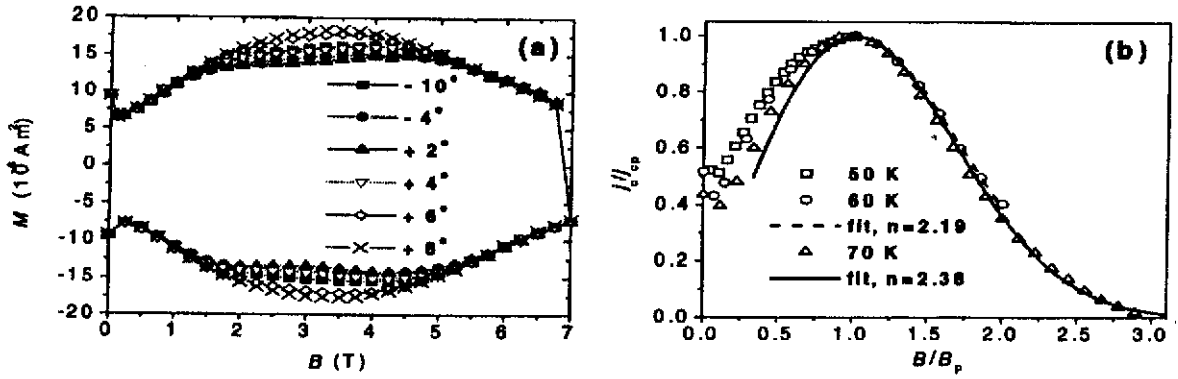


Fig.1. (a) Angular dependence of MHL at 60 K for Nd-123 single crystal with a simple single-domain twin structure, (b) normalised  $j_c(B)$  curves for different temperatures and a fit by means of eq. (1).

verned mainly by a mutual collective pinning. From a good scaling of  $F_p/F_{pmax}$  vs.  $h=H/H_{irr}$  we deduced that the main mechanism for collective pinning in the NdBCO single crystals is of the  $\Delta\kappa$  type [6].

On the basis of the present angular measurements, the intermediate peak observed in twinned  $NdBa_2Cu_3O_{7.8}$  single crystals [1,6] could be identified with a start of an intensive twin-structure pinning. The temperature independence of the "peak" position implies that the pinning crossover is initiated by a matching effect. The effective twin distance deduced from the field is  $\approx 30-35$  nm.

Figure 2 shows scaling of the  $j_c(B)$  curves in the "clean" fishtail regime and the fit by means of the phenomenological formula developed for pinning by point-like, non-correlated disorder [5],

$$j_{sc}=b*\exp[(1-b^n)/n] . \quad (1)$$

Here,  $j_{sc}$  and  $b$  are the critical current density and applied field normalised with respect to the fishtail maximum co-ordinates, respectively. The width of the normalised curves increases slightly with decreasing temperature so that the curves do not scale perfectly between 50 and 70 K. Nevertheless, their high-field parts are always well described by eq. (1), with  $n$  varying between 2.2 and 2.5. It seems that presence of a twin structure particularly affects pinning at fields below the fishtail peak where the fit is not satisfactory. This can hardly be due to a central peak contribution only, especially at high temperatures.

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