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Local magnetic relaxation close to the second peak in BSCCO crystals

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Local magnetic relaxation measurements were performed on $Bi_2Sr_2CaCu_2O_{8+x}$ (BSCCO) single crystals using a Hall-sensor array. The recorded field profiles provide unambiguous evidence of a crossover from surface barrier to bulk pinning in the second magnetization peak region. Both contributions to the magnetization exhibit a pronounced relaxation. For fields above the second peak we observe an additional crossover from bulk-pinning at short time scales, with Bean-like profiles, to dome-shape profiles originating from surface barrier at long times.

1. INTRODUCTION

The second magnetization peak observed in highly anisotropic high-temperature superconductors has attracted intense experimental work recently. The temperature region (20-40K) where the jump in the equilibrium magnetization related to the first order phase transition [1] transforms to a peak in the irreversible magnetization [2] is of particular interest. Commonly used global magnetization measurements are unable to distinguish bulk from surface contributions to the irreversible magnetization, which leads to serious misunderstanding of the underlying phenomena. Here we present direct evidence of field and time dependent crossovers between surface and bulk pinning in the peak region.

2. EXPERIMENT

Two samples ($230 \times 180 \times 20$ μm^3 and $650 \times 330 \times 30$ μm^3) were cut from the same BSCCO crystal already used in previous work [3]. The Hall-arrays were fabricated from GaAs/GaAlAs heterostructures. The samples were placed on top of arrays of 11 sensors, each of area 10×10 μm^2, and spaced by 10 μm, or of area 3×3 μm^2, spaced by 3 μm. The set-up was placed in a temperature-controlled sample holder inside a coil providing a field Ha parallel to the c-axis of the crystal. Isothermal magnetization loops were recorded after zero-field-cooling from above T_c. From the sets of local magnetic induction $B_z(x)$ measured on each sensor after each step in field, we reconstructed the flux profiles. Magnetic relaxation was recorded at constant field Ha, reached after a fast field ramp down from higher, and up from lower values in order to trigger activated flux-penetration and flux-exit.

3. RESULTS

Typical magnetization loops recorded at different locations on the sample surface at $T = 25.6$ K are presented in Fig. 1. Two regimes are clearly distinguished: low field, characterised by the near-absence of a field gradient; and a high field region where gradients appear. The appearance of gradients corresponds to the second magnetization peak observed in both global and local magnetic measurements.

More insight in the origin of the magnetization can be obtained from the analysis of the magnetic field profiles, shown in Fig. 2. The local magnetic induction from all sensors was recorded as function of time at constant temperature and field, after increasing the external field from 0 to H_a. We present the evolution of the field profiles at two representative H_a -values below and above the second peak, which in the sample investigated is situated at 380 Oe. At applied fields below the second peak (upper panel of Fig. 2), we observe dome-shaped profiles as expected for a magnetization originating from a surface barrier [4]. The time evolution of those profiles is governed by the decay of the current in a narrow region close to

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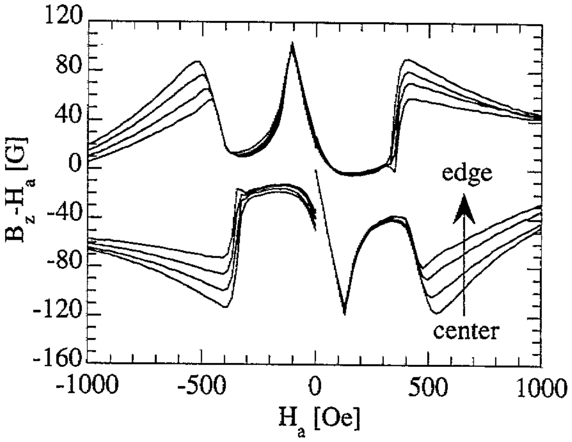

Figure 1. Hysteretic loops of the local magnetization recorded at $T = 25.6$ K at various locations on the sample surface. The distance between consecutive sensors is 18μm.

the sample edge, and is characterised by a continuous upward shift of the flux dome inside the sample. In contrast, at fields above the second peak (lower panel of Fig. 2), Bean-like profiles are observed at short times. However, the slope of Bean-like profile quickly decreases with time, and a dome shaped profile is recovered after waiting a sufficiently long time. This evolution of field profiles as function of time is direct evidence of a crossover from bulk pinning to the surface barrier in determining the magnetization. The same crossover can be observed as function of time during the flux exit process when the applied field is decreased from much higher value.

4. CONCLUSION

The demonstrated field and time dependent crossover in the magnetisation has several consequences for the analysis of both local and global measurements in clean BSCCO crystals.

(1) The values of the integral irreversible magnetisation below and above the second peak cannot be compared directly because they have different origins.

(2) The lower decay rate of that part of the magnetisation that is determined by the surface barrier with respect to the decay of the bulk contribution leads to an apparent decrease of the flux-creep activation energy as the field is increased beyond the second peak-field. This decrease is therefore not representative of the bulk pinning behaviour.

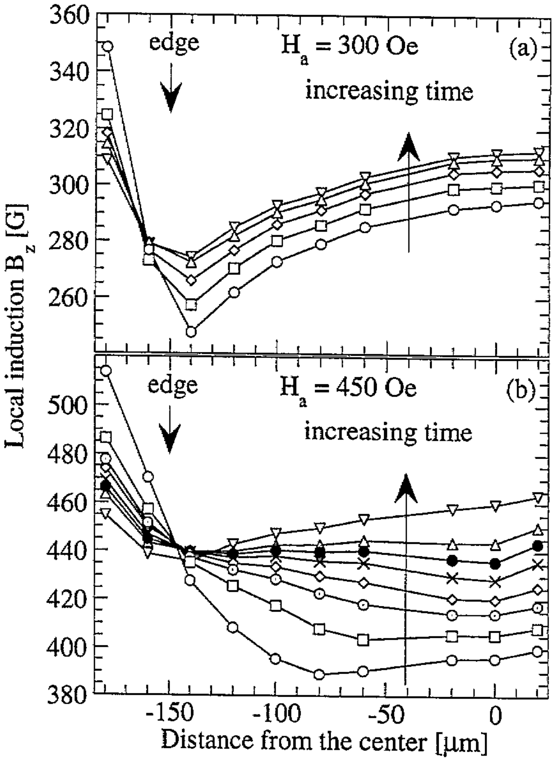

Figure 2. Magnetic field profiles recorded in function of time after increase of applied field from zero to 300 Oe (upper panel) and 450 Oe (lower panel). Time interval was from 0.06 to 2000 s in constant steps in logarithmic scale ($T = 25.6$ K).

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