

ON THE MAGNETIC MOMENT RELAXATION IN YBaCuO SINGLE CRYSTAL : SUB-SECOND RELAXATION TIMES

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Abstract

Magnetic moment relaxation at constant sweep rate $\dot{B}=dB_{\text{ext}}/dt$ (so called hysteresis loop relaxation) was measured in YBaCuO single crystal platelet by means of vibrating sample magnetometer. In this way it is possible to analyze the range of very short effective relaxation times not allowed by conventional relaxation. In the range of high sweeping rates \dot{B} corresponding to sub-second effective relaxation times deviation from $\ln(t)$ dependence was observed. This difference may be due to some other effect, probably viscosity of flux line lattice.

1. INTRODUCTION

Microscopic theories have not yet succeeded to explain satisfactorily processes connected with large critical current relaxation in HTS. We are still dependent on phenomenological models well established in conventional superconductors and adopted to the field of HTS. One of them, Bean's model, relates magnetic moment m induced in a superconductor by varying external magnetic induction B_{ext} to critical current density j_c [1]. Relaxation phenomena in superconductors are explained by other phenomenological model in terms of thermally activated flux creep [2,3]. According to this model magnetic moment m induced in constant external magnetic induction B_{ext} logarithmically decreases with time, in good agreement with most experiments performed in a wide range of times (from seconds to hours).

It can be expressed as

$$m(t) = m_1 - S \ln(t) \quad (1a)$$

where m_1 and S are independent of time,

$$m_1 = m_0 \left(1 + \frac{kT}{U_0} \ln(t_0)\right); \quad S = m_0 \frac{kT}{U_0} \quad (1b)$$

Here t_0 is the mean time between two hopping attempts from one pinning center to another, m_0 is the magnetic moment in absence of relaxation.

It has been shown in [4,5] that thermally activated flux motion can also explain magnetic moment dependence on sweep rate in the $\dot{B}=\text{const.}$ regime (hysteresis loop relaxation, HLR). It is assumed that relaxation effect is here opposed by the rise due to Lorentz forces so that equilibrium is established for

$$m(\dot{B}) = D_m + S \ln|\dot{B}| \quad (2)$$

where D_m and S are independent of \dot{B} and the relaxation rate S should be same in (1a) and (2) [4,5].

In this model each hysteresis loop can be labeled with an effective time

$$t_{\text{eff}} = \frac{\mu_0 S}{\chi \dot{B}} \quad (3)$$

where χ is differential susceptibility, $\chi = \mu_0 \Delta m / \Delta B_{\text{ext}}$, and μ_0 permeability of vacuum. Magnetic moment of a superconducting sample placed in the magnetic field sweeping with a constant \dot{B} has the same value as after relaxation for time t_{eff} at constant B_{ext} . Eq. (3) can be used for comparison of HLR and conventional relaxation at $B_{\text{ext}}=\text{const.}$ on the same time scale.

2. EXPERIMENTAL

Magnetic moment of the YBaCuO single crystal platelet of 2.12 mm^2 area (a-b plane), thickness $30 \text{ }\mu\text{m}$ and mass 0.401 mg was measured by vibrating sample magnetometer at temperatures from 7K to 44K , fields $\pm 2\text{T}$ and sweep rates \dot{B} from 89 to 0.08 mT/s . The overshooting of B_{ext} was eliminated even at the

highest sweep rate. Magnetic moment was measured with magnetic field along c-axis. Differential susceptibility χ was measured at each particular field by demagnetizing sample by means of ac signal of logarithmically decreasing amplitude and then applying the ac signal of appropriately small constant amplitude.

Special attention was paid to well defined measurement conditions. Magnetic field was recorded simultaneously with magnetic moment for its later check. Field stability at the $B_{\text{ext}} = \text{const.}$ regime was typically $\pm 6 \cdot 10^{-5}$, field sweep linearity at the $\dot{B} = \text{const.}$ regime better than $2 \cdot 10^{-4}$. Temperature was kept constant within $\pm 0.1\text{K}$.

3. RESULTS AND DISCUSSION

HLR results measured at $T=21\text{K}$ and $B_{\text{ext}} = \pm 0.6\text{T}$ and $+1\text{T}$ are on the left-hand side of Fig. 1 (points connected by dashed lines as guides for eye). The right-hand side of the figure (full lines) shows logarithmic fits of measured conventional relaxations. The significant upwards declination of measured magnetic moment from logarithmic time dependence with increasing sweep rate (decreasing t_{eff}) is apparently due to increasing role of viscous forces opposing to relaxation. It qualitatively corresponds to theoretical predictions for the limiting case of viscous flux flow without relaxation [6]. In this case magnetic moment linearly depends on \dot{B} so that using eq. (3)

$$m(\dot{B}) = A + \frac{C}{t_{\text{eff}}} \quad (4)$$

where A and C are independent of \dot{B} .

The temperature dependence of the relaxation processes is plotted in Fig. 2. Extensive measurements between 7K and 44K showed that in this temperature range relaxation rate S is in both types of experiments nearly the same function of temperature, approximately $S \sim T^{-1.5}$.

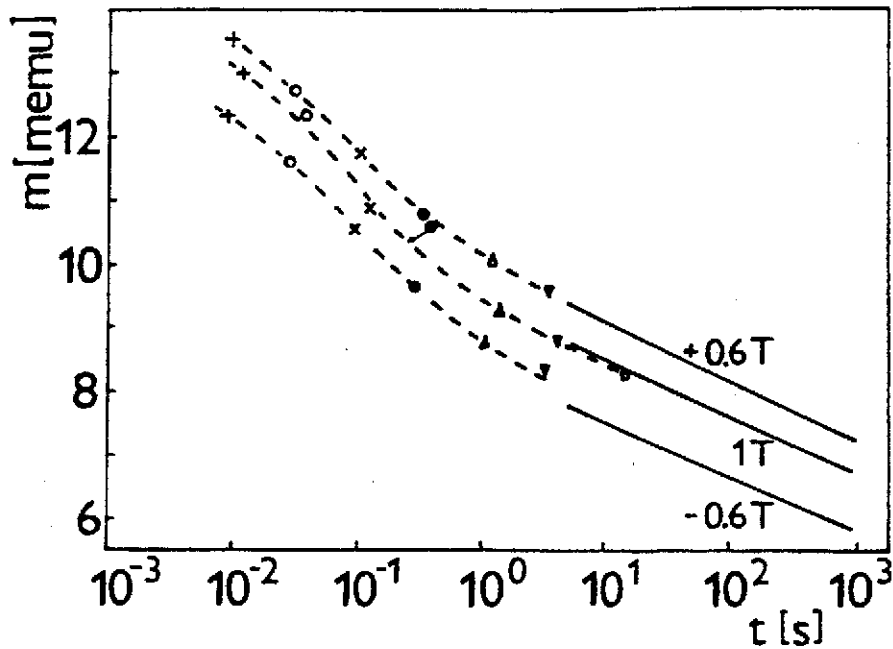


Figure 1. Hysteresis loop and conventional relaxations measured at $T=21\text{K}$ and $B_{\text{ext}} = +0.6\text{T}$ and $+1\text{T}$. The signs $+$, o , x , \bullet , Δ , ∇ and \square correspond to $\dot{B}=89, 29, 8.9, 2.9, 0.88, 0.29$ and 0.08mT/s , respectively.

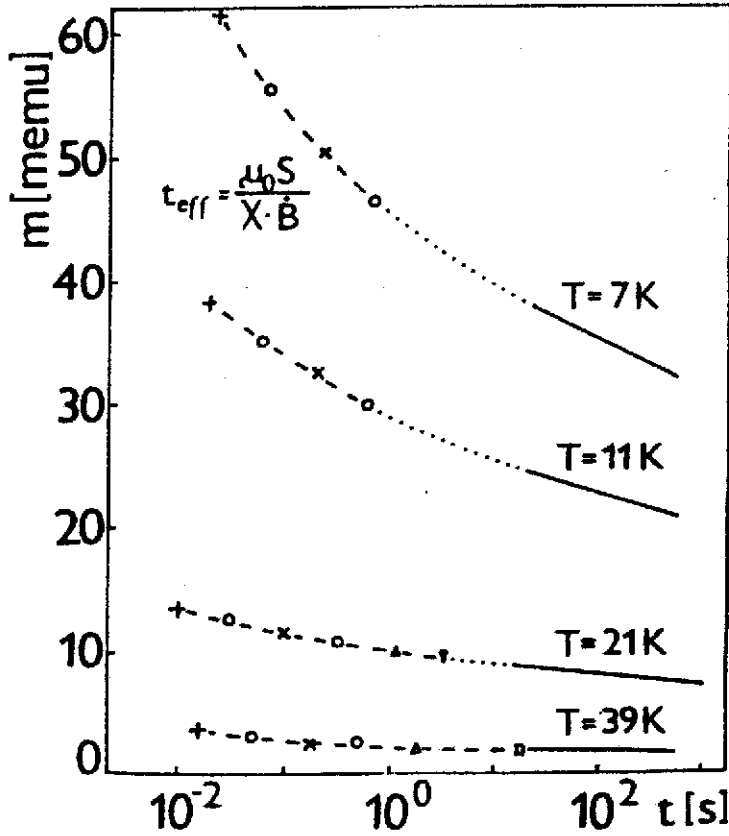


Figure 2. Hysteresis loop and conventional relaxations measured at $B_{\text{ext}}=+0.6\text{T}$ for different temperatures from 7K to 39K . The signs $+$, o , x , \bullet , Δ , ∇ and \square correspond to $\dot{B}=89, 29, 8.9, 2.9, 0.88, 0.29$ and 0.08mT/s , respectively.

4. CONCLUSIONS

Magnetic moment relaxation in the vortex lattice exposed to the sweeping magnetic field is influenced by some additional mechanism dependent on sweep rate which retards the relaxation rate. The temperature dependence of the relaxation rate is nearly the same for both conventional and loop relaxation.

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