Magnetostriction and Magnetoacoustic Measurements on pure and Zn-doped YBCO Crystals

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Abstract

Magnetostriction hysteresis data reveal the presence of the fishtail effect in isothermal scans between 72 K and 80 K. Thermal cycles in a constant magnetic field show the behaviour of pinning of flux lines in the different phases. Ultrasonic attenuation and the relative change of the sound velocity for various magnetic fields were measured. The aim is to examine the elastic behaviour of the flux line lattice. In the framework of the thermally assisted flux flow model (TAFF) the depinning temperature T_D(B) and the activation energy U(B) were been deduced. The measurements on YBCO crystals are discussed and compared with investigations on YBCO/Zn+Ag composites. The magnetostrictive effects are verified by supplementary DC-magnetization measurements.

Key words: magnetostriction;vortex melting;$YBa_2Cu_3O_7$

1. Introduction

A contemporary view based on the results of the experimental investigations and theoretical studies [1] on the vortex state suggests that the magnetic phase diagram of YBCO comprises phases, like an ordered vortex solid (Bragg glass with no dislocations), a disordered solid (vortex glass with proliferation of dislocations) and a vortex liquid divided by several phase transition lines.

Recent studies have focussed on the anomalous magnetization peak near the upper critical magnetic field B_{C2}, called fishtail effect (FE) or peak effect. It has been widely suggested that the FE is related to an underlying melting of the the flux line lattice (FLL) [2].

We show with magnetostriction and magnetization measurements that for low fields the FLL first order melting occurs near the irreversibility line.

2. Experimental

Melt-textured YBCO bulk samples were prepared with the help of SmBaCuO seed crystals [3]. The superconducting transition temperature is reduced from 91.5 K for the pure YBCO crystal to 89 K for the Zn doped YBCO/Zn+Ag composite.

Isothermal and isofield magnetostriction measurements on YBCO and on the composite were carried out in magnetic fields of up to 8 T using a capacitance dilatometer. The examined samples are cubic with a side length of about 6 mm. At these probe dimensions the resolution of the relative change of length of our dilatometer achieves $\Delta l/l_0 = 10^{-8}$. The B-sweeps were performed with a rate of 10 mT/s and the warming up ramps with a rate of 20 mK/s.

The ultrasonic attenuation was measured at 10 MHz by the pulse-echo technique.

All measurements where carried out with the c-axis of the probes parallel to the magnetic field applied.

3. Results and Discussion

The magnetostriction data reveal the presence of the FE for the pure YBCO crystal in isothermal scans between 72 K and 80 K. Fig. 1 shows closed fishtail curves for the pure YBCO and for the composite at T = 77 K.

It is possible to determine the irreversible magnetic field B_{irr}, where the distribution of the flux lines is reversible respectively to changes of the magnetic field: B_{irr}(YBCO) = 7.6 T, B_{irr}(YBCO/Zn+Ag) = 5.5 T.

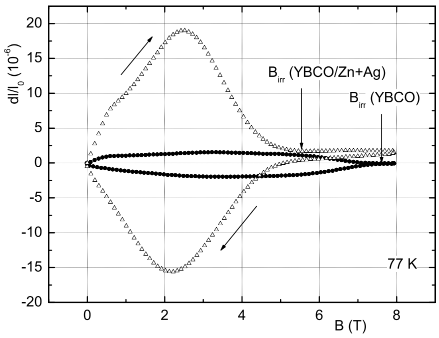

Fig. 1. The relative change of length of a pure YBCO crystal (filled circles) and a YBCO/Zn+Ag composite (open triangles) vs. magnetic field at the constant temperature T = 77 K.

The broad fishtail peaks are typical of impure samples. The FE is caused by impurities, point defects and clusters from oxygen vacancies that act as pinning centers. Doping with Zn increases the number of the pinning center. This results in a more distinct FE for the composite (Fig. 1).

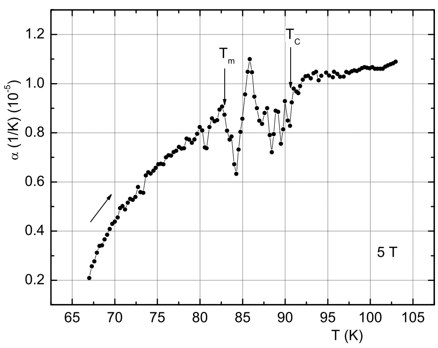

Fig. 2. Thermal expansion coefficient $\alpha = l^{-1} \cdot$ (dl/dT) vs. temperature for a pure YBCO crystal at constant magnetic field B = 5 T (zero field cooled).

At low magnetic fields, which are below the fields for the appearance of the FE, the ordered Bragg-glass phase transforms at characteristic temperatures T_m by a first order transition to a vortex liquid [4]. In Fig. 2 an isofield warming-up measurement with a constant magnetic field of 5 T for the pure YBCO crystal is shown. The first order melting induces a jump in the thermal expansion coefficient α at T_m = 82.8 K.

Fig. 3 shows the magnetization of the composite as a function of temperature in zero field cooled (ZFC) and field cooled (FC) modes at a constant magnetic field of 3 T. A discontinuous magnetization jump is observed at the first order vortex lattice melting temperature of T_m = 80.9 K, which is located 1.9 K above the temperature for the irreversibility T_{irr}. The point, where the ZFC and the FC curves diverge, determines T_{irr}.

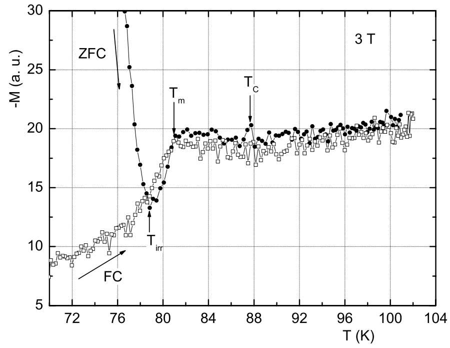

Fig. 3. Isofield magnetization data of the YBCO/Zn+Ag composite at B = 3 T vs. temperature. In comparison of the ZFC and FC measurements T_m, T_{irr} and T_C can be determined.

Ultrasonic attenuation measurements were carried out at constant magnetic fields. The propagation direction of the transverse sound wave is parallel to the applied magnetic field. The maximum of the peak of the ultrasonic attenuation defines the depinning temperature T_{dep} [5]. The depinning temperature results to T_{dep}(4 T) = 81.7 K, T_{dep}(5 T) = 80.3 K for the YBCO/Zn+Ag composite and to T_{dep}(4 T) = 81.9 K, T_{dep}(5 T) = 81 K for the pure YBCO sample.

For the composite the activation energies are with U(4 T) = 64.2 meV and U(5 T) = 63.1 meV greater than for the pure YBCO sample: U(4 T) = 63.5 meV and U(5 T) = 62.8 meV.

References

[1] T. Giamarchi and P. Le Doussal, Phys. Rev. B 55, 6577 (1997)

[2] A. I. Larkin, M. C. Marchetti and V. M. Vinokur, Phys. Rev. Lett. 75, 2992 (1995)

[3] G. Krabbes, G. Fuchs, P. Schtzle, S. Gruss, J. W. Park, F. Hardinghaus, R. Hayn, S.-L. Drechsler, Physica C 341-348, 2289 (2000)

[4] N. Kobayashi, T. Nishizaki, K. Shibata, T. Sato, M. Maki and T. Sasaki, Physica C 362, 121 (2001)

[5] J. Pankert, G. Marbach, A. Comberg, P. Lemmens, P. Frning, S. Ewert, Phys. Rev. Lett. 65, 3025 (1990)