Journal of Alloys and Compounds 421 (2006) 4–7

Journal of ALLOYS AND COMPOUNDS

www.elsevier.com/locate/jallcom

Effect of dc bias field superimposed with ac field amplitudes on the hysteresis loss in a sintered YBCO superconductor

A. Öztürk, S. Çelebi *

Department of Physics, Faculty of Science and Arts, Karadeniz Technical University, 61080 Trabzon, Turkey

Received 24 August 2005; accepted 22 September 2005
Available online 18 January 2006

Abstract

We have investigated the magnetic behaviour of a sintered YBCO sample by ac susceptibility measurements in the presence of a static bias dc magnetic field. Calculations of the imaginary part of the ac susceptibility or hysteresis losses have been performed to account for the measured ac loss valley. Our calculations based on the critical state model with $j_c = \alpha(T)/B^n$ reproduce the experimental data quite well. We also explored the effect of temperature exponent in the pinning strength parameter on the ac loss valley behaviour.

PACS: 74.60Ge; 74.60Jg

Keywords: YBCO; Critical state model; Critical current density; ac loss valley

1. Introduction

It is well known that the behaviour of ac losses in type II superconductors can be investigated measuring the ac susceptibility [1–3]. Some researchers [4–7] have observed that ac losses in a variety of classical type-II superconductors show a valley when the energy dissipation W per unit volume and per cycle for a fixed amplitude H_{ac} of the applied magnetic field H_a is measured at constant temperature T and constant low frequency f as a function of a bias static magnetic field H_b that is collinear with H_{ac}. This feature was referred to as the Clem valley in Refs. [7,8]. Clem has investigated this phenomenon theoretically in the framework, where (i) bulk pinning, (ii) equilibrium diamagnetism and (iii) surface barrier to entry and exit of flux, are taken into account. It is noted that field dependence of bulk pinning alone can give a minimum. LeBlanc et al. [9] have focused on the variation of peak loss χ''_{max}, with H_b over the range $0 \le H_b \approx H_{*0}$ and $H_{ac} \le H_{*0}$ in the framework of the critical-state model for slab geometry, where H_{*0} is the full penetration field at $T = 0$ K. They found that, χ''_{max} versus H_b displays a "ac-loss valley" in the presence of H_b superimposed to ac field H_{ac}.

In this article, we present experimental ac susceptibility measurements on a sintered YBCO sample, where H_{ac} is varied and H_b is kept fixed. The observed ac loss valley has been accounted by the theoretical calculations based on power law critical state model, $j_c = \alpha(T)/B^n$, where α is temperature dependent pinning strength parameter. We note that ac loss valley observations and model to account for observed data, where H_b is kept fixed and H_{ac} is varied, is first presented in our previous communication in ZnO added YBCO sample [10]. In this work, we not only present the similar observations in a different sample as an extention of [10] but also report on the effect of temperature exponent p in the expression of pinning strength parameter $\alpha(T) = \alpha_0(1 - T/T_c)^p$ on the ac loss valley behaviour.

2. Experimental

The sample studied in this work was prepared by conventional solid state reaction method. The powders of Y_2O_3, $BaCO_3$, and CuO were thoroughly mixed in the appropriate amounts and calcined at 940 °C for 24 h. After calcination, the powders were mixed by a grinding machine for 4 h and then pressed into pellets of 13 mm diameter at 375 MPa. The pellets were sintered at 945 °C for 24 h and cooled down to room temperature at a cooling rate of 1 °C/min by flowing oxygen at temperatures between 700 and 250 °C. Details on the microstructure of the sample can be found elsewhere [11].

ac susceptibility of the sample is measured with a commercial Lake Shore susceptometer model 7000. The dimensions of the sample for ac susceptibility measurements are 2.54 mm × 2.72 mm × 12.92 mm. The sample was mounted

* Corresponding author. Tel.: +90 462 325 8244; fax: +90 462 325 3195.
E-mail address: celebi@ktu.edu.tr (S. Çelebi).

0925-8388/$ – see front matter
doi:10.1016/j.jallcom.2005.09.086

such that its length was along the direction of the magnetic field. The temperature was varied using a closed cycle helium cryostat equipped with a temperature controller. The signal due to the in-phase and out-of-phase magnetization were taken simultaneously.

3. Results and discussions

We display the temperature behaviour of the ac susceptibility for the sample at various ac field amplitudes (rms) in Fig. 1, where $H_b = 0$. We normalized experimental ac susceptibility data $\chi''(T)$ and $\chi'(T)$ to the $|\chi'|$ at the lowest temperature and the lowest field amplitude for each sample since the demagnetizing correction would cause $\chi' = -1$ for low enough temperature at low field amplitude. The loss peaks shift to lower temperature by increasing field amplitudes. The diamagnetic transition temperature is found to be 93 K for the sample. Two-step structure in real part (χ') is clearly seen, which reflects the shielding of flux from and between the grains as T decreases. When the sample is at just below T_c, the superconducting grains first shield the applied magnetic field. This is measured as a negative χ'. At low enough temperature, intergranular component of χ' appears. At extremely low temperatures the whole volume of the sample is expected to be shielded by the supercurrent circulating in the sample and hence the curve of χ' versus T saturates.

Fig. 2 shows the temperature variation of the ac matrix susceptibility χ''_m at $H_b = 400$ A/m and various ac field amplitudes for the YBCO sample. We note that we have observed similar behaviour in a 1 wt.% ZnO added YBCO sample for which detailed measurements and calculations can be found elsewhere [10].

In Fig. 3, we display the field dependence of the peak temperature for the sample. The peaks in $\chi''(T)$ shift to lower temperatures with increasing field amplitudes. The amount of the shift as a function of the field amplitude is proportional to the strength of the pinning force. Comparing any two samples, the larger the shift in the maxima of χ'', the weaker the pinning and hence the smaller j_{cm} will be. The relation between first penetration field for matrix H_{*m} and the peak temperature T_p can

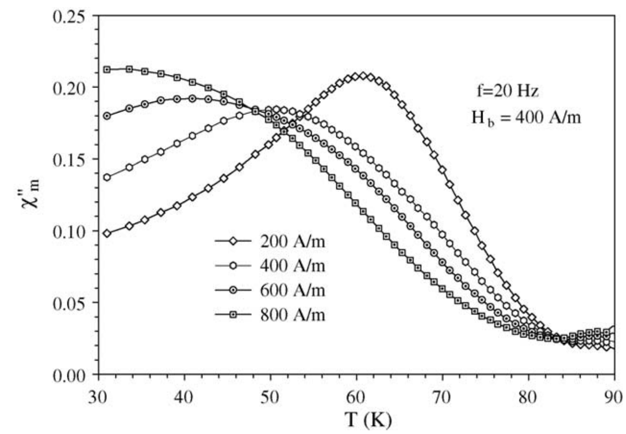

Fig. 2. Temperature dependence of extracted matrix susceptibility χ''_m for field amplitudes ranging from 200 to 800 A/m with $f = 20$ Hz in the presence of a collinear static bias field $H_b = 400$ A/m.

be written as follows.

$$H_{*m}(T) = \left[(n+1)\alpha_0 R\left(1 - \frac{T_p}{T_{cm}}\right)^p\right]^{1/(n+1)} \quad (1)$$

$$H_{*m0} = [(n+1)\alpha_0 R]^{1/(n+1)} \quad (2)$$

where α_0 is the pinning strength parameter at $T = 0$, p is the temperature exponent of the pinning strength or critical current density, n is a parameter indicating the field dependence of the intergranular critical current density and R is the radius of the cylinder or half thickness of the slab. We calculated best fit curve using the parameters $p = 1.8$, $n = 0.2$, $T_{cm} = 86$ K and determined H_{*m0} as 1700 A/m (H_{*m} at $T = 0$).

In Fig. 4, we compare the calculated curves with the experimental matrix susceptibility for the sample where $H_b = 400$ A/m and field amplitudes range from 200 to 800 A/m. The fitting parameters are as follows: $n = 0.20$, $p = 1.8$, $T_{cm} = 86$ K and $H_{*0} = 1700$ A/m. The families of curves of χ_{hys} versus T displayed in Fig. 4 illustrates the effects of weak bias fields H_b on the magnitude and position of the peak value, $\chi_{hys,max}$ for the

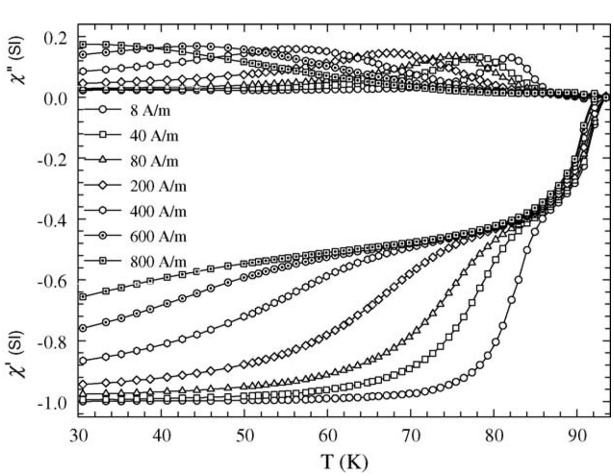

Fig. 1. Temperature variation of ac susceptibility at field amplitudes H_{ac} ranging from 8 to 800 A/m with $f = 20$ Hz for the sample in the absence of H_b.

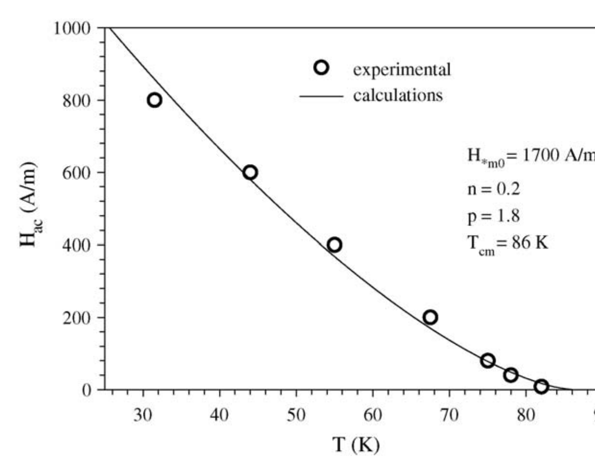

Fig. 3. Plot of penetration field H_{ac} as a function of peak temperature in the absence of dc bias field. Open circles are for experimental data and solid line is for the calculated best fit curve using the parameters given on the legend.