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ORIGINAL PAPER

The Effect of Y_2O_3 on AC Susceptibility Measurements of MPMG YBCO Superconductor

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Abstract In this study, two kinds of melt-powder-melt-growth (MPMG) YBCO sample grown on a buffer layer of Y_2O_3 addition were fabricated. The compacted powders were located on a crucible with Y_2O_3 powder freely poured and a buffer layer of pressed Y_2O_3. AC susceptibility measurements of the samples as a function of temperature was reported for several different AC magnetic-field amplitudes (H_{ac}) in the presence of static bias magnetic field (H_b) directed along H_{ac}. The loss peaks are found to shift towards lower temperatures as the AC field strength is increased. The frequency effect on the AC susceptibility was also measured. As the frequency increases, the peak temperature shifts to higher temperature. This effect can be interpreted in terms of flux creep.

Keywords AC susceptibility · MPMG YBCO · Y_2O_3 buffer layer

1 Introduction

High temperature superconductors (HTS) have significant potential for practical applications, based on their ability to carry transport current in the presence of relatively high magnetic fields at 77 K. Melt processing of YBCO superconductors is an effective technique for fabrication of large superconducting grains with high critical current density (J_c). Flux-pinning centers in the sample are required to support such currents such as nonsuperconducting second phase particle inclusions in the superconducting matrix [1]. Also, the control of the growth process conditions is important to create homogeneous, monolithic samples with a large number of intrinsic flux-pinning centers. The flux-pinning properties of Y_2O_3 in YBCO thin films prepared by sputtering and metallorganic vapor deposition (MOCVD) have previously been reported [2, 3]. The use of Y_2O_3 nanoparticles showed a potential as flux-pinning centers in YBCO thin films [2].

AC magnetic measurements $\chi = \chi' + i\chi''$ have been widely used to study the magnetic properties and flux dynamics of superconductors. The real part reflects the screening properties expressed as a difference in the energy of the sample between the nonsuperconducting and the superconducting states. The imaginary part corresponds to the energy dissipation and the ac losses related to pinning properties of the sample [4]. Thus, pinning losses are independent of frequency but dependent on the field, whereas flux flow losses depend on the frequency, not on the field [5].

Since AC measurements are widely used to analyze the magnetic properties of HTS, in the present work a comparison between the properties of melt-powder-melt-growth (MPMG) YBCO samples produced different buffer layer was performed.

2 Experimental Procedure

$YBa_2Cu_3O_{7-x}$ (Y123) powders containing high purity powders of Y_2O_3, $BaCO_3$ and CuO were fabricated by melt-powder-melt-growth (MPMG) process. The powders were mixed for 1 h and were calcined at 900 °C for 30 hours in

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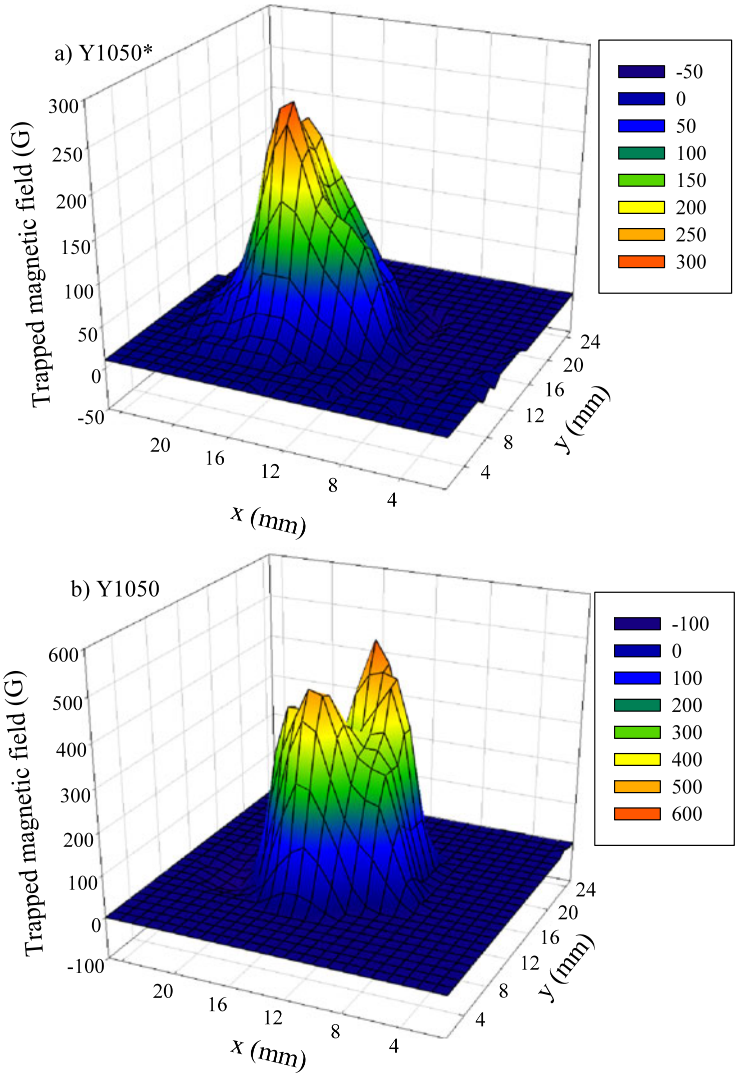

Fig. 1 Trapped magnetic-field distributions for the samples (**a**) Y1050* and (**b**) Y1050 [6]

air atmosphere. Then fine powders placed into a platinum crucible was quenched by pouring onto a copper plate from 1450 °C to room temperature. The thin platelets obtained were ground again for 1 hour. In this study, two kinds of MPMG YBCO sample (Y1050 and Y1050*) were fabricated for a growth temperature of 1050 °C. While the sample Y1050 was located on a crucible with a buffer layer of pressed Y_2O_3, the sample Y1050* was located on a crucible with a buffer layer of freely poured Y_2O_3 powder. The details of the single crystal growth process are described in [6]. After the crystal growth process, the samples were annealed at 500 °C for 24 h in flowing oxygen and then cooled to room temperature at a rate of 1 °C/min in oxygen.

AC magnetic measurements were performed in the Quantum Design Physical Property Measurement System (PPMS), using the so-called ACMS, with the field parallel to the c-axis of the sample placed at the center of the sample holder. AC susceptibility measurements of the samples, as a function of temperature, for different AC magnetic-field amplitudes (H_{ac}: 1 Oe, 10 Oe) in the presence of static bias magnetic fields ($H_b = 0$ T, 1 T, 2 T and 4 T) was performed by using frequencies of 20 Hz and 1000 Hz. For all measurements, the sample was cooled down in zero field and then warmed up at a constant rate of 1 K/min. Details of further observations on their magnetic behavior can be found in [7].

3 Results and Discussion

Figure 1 shows the trapped magnetic-field distributions for the samples Y1050* (freely poured Y_2O_3 buffer layer) and Y1050 (pressed Y_2O_3 buffer layer). Although the trapped magnetic field of the Y1050 sample is higher than that of the Y1050* sample, Y1050* seems like single crystal when compared to Y1050. It was thought that pinning properties of Y1050 are better than Y1050*, and Y1050 is much stronger than Y1050* against an external magnetic field [7].

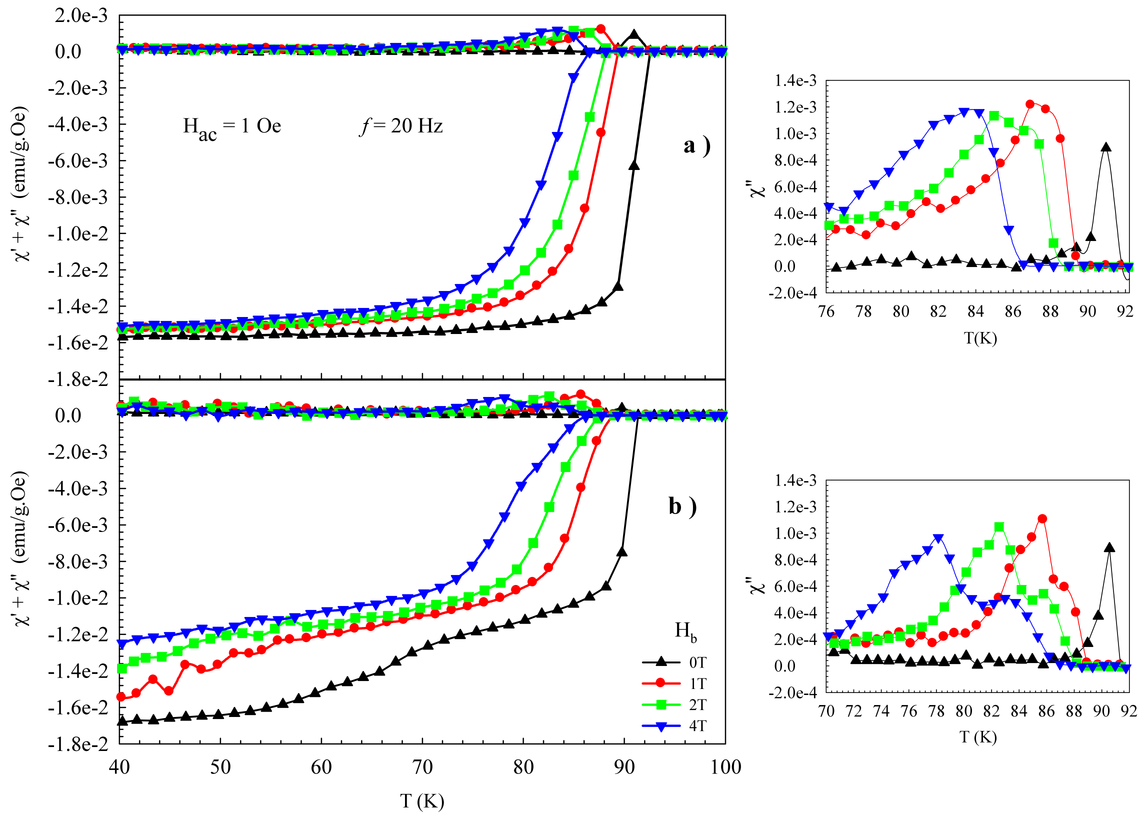

Fig. 2 Plot of real (χ') and imaginary (χ'') components of AC susceptibility as a function of temperature of (**a**) Y1050* and (**b**) Y1050 taken at applied AC field amplitudes H_b, ranging from 0 to 4 T at a frequency $f = 20$ Hz

The temperature variation of fundamental AC susceptibility measured at different bias fields in 1 Oe AC field on small specimens cut from the Y1050* and Y1050 samples are shown in Fig. 2. The real part of Y1050* shows a single sharp diamagnetic transition, while Y1050 consists of two transition corresponding to flux exclusion from intra- and inter-granular regions. In the presence of 1 Oe AC field, the super currents initially circulate around the individual grains and a drop in χ' is observed at this temperature. The flux is removed from inter-grain region and reflected by a second drop for Y1050. At very low temperatures both inter-grain and intra-grain regions are excluded from flux when complete shielding is reached [8]. This is indicated by saturation of χ' at very low temperatures [9]. The level of saturation at low temperatures becomes less negative with increase in bias field indicating a decreasing in the shielding ability of the sample. This is explained by the increase in vortices produced due to field penetration of the sample [4]. This behavior is much bigger for Y1050 because of its granularity. So Y1050* is almost single crystal, an increasing of bias field does not affect saturation level so much. The appearance of a peak in the χ'' versus temperature is a very common feature associated with the superconducting transition. The peak in χ'' occurs at the point where the AC magnetic field just reaches the center of the sample approximately [10]. The maximum occurs at a temperature T_p which is lower than the critical temperature T_c, and T_p and T_c values shift to lower temperatures with increasing applied bias field. In Fig. 1 Y1050* represents a single peak but Y1050 two peaks, from which it can be stated that all the samples exhibit inter-granular couplings as well as intrinsic granular interactions of the imaginary part of AC susceptibility [4, 11]. It is known that the amount of the shift as a function of the amplitude is proportional to the magnitude or strength of the pinning force. The larger the shift in the maxima of χ'' is, the weaker the pinning [12]. It can be seen that shifting of T_p values which was proportional to AC losses with applied field for Y1050 is larger than Y1050* shown in Fig. 3. It can be seen that the Y_2O_3 buffer layer freely poured both decreases pinning losses according to being pressed and it supports the crystal growth. Nevertheless, for the Y1050 specimen the intra granular peaks (T_g) was noticed for the 1 T and further fields. The lack or missing of the intra-grain peaks is due to overlapping with the much broader inter-grain T_p peaks [4].

Figure 4 shows a plot of the AC susceptibility as a function of temperature of Y1050* and Y1050 taken at applied different AC fields, at a frequency $f = 1000$ Hz, in the ab-

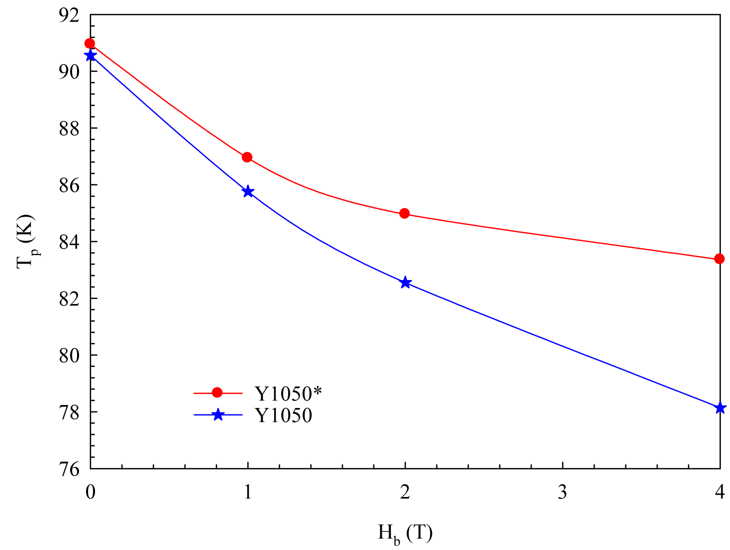

Fig. 3 The peak temperature T_p (K) of χ'' versus different H_b (T) for Y1050* and Y1050

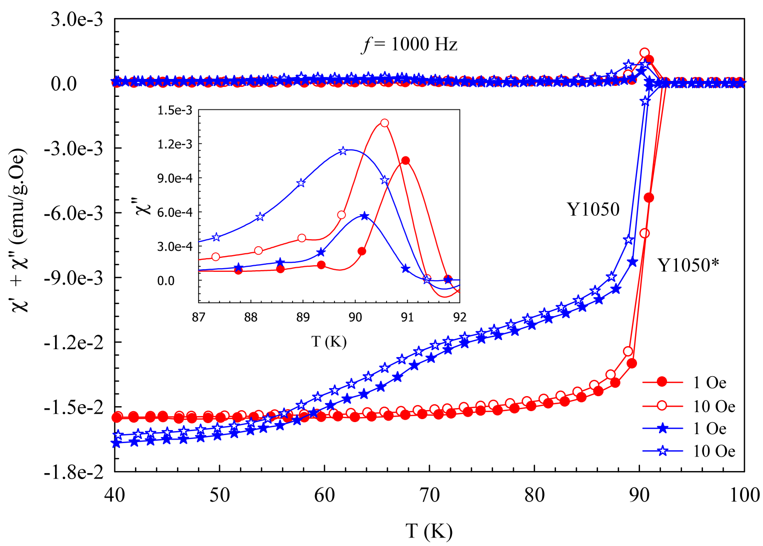

Fig. 4 Plot of (a) real (χ') and (b) imaginary (χ'') components of AC susceptibility as a function of temperature of Y1050* and Y1050 taken at applied different AC fields, at a frequency $f = 1000$ Hz

sence of a bias field. It is clearly shown in the figure that the real part has a diamagnetic phase transition at around 92 K for Y1050* and a hump transition for Y1050. Also, the T_p values shift to lower temperature with increasing applied AC field magnitude and Y1050 had been affected a little from variation of AC field rather than Y1050* because of its poly-crystal structure. Normally there was not much difference between the values, so it was thought that Y1050 has a strong interconnectivity between the grains.

Figure 5 shows plot of AC susceptibility as a function of temperature of Y1050* and Y1050 taken at applied AC field amplitude H_{ac} 10 Oe, at frequencies 20 and 1000 Hz, in the absence of a bias field. The determined T_p values from the χ'' curves reported in Fig. 5 show the increase of both the temperature and the amplitude of the peak with the frequency. This effect can be interpreted in terms of flux creep or magnetic relaxation [8]. Since the pinning force density weakens with increasing temperature, the peak temperature, T_p, must increase with increasing frequency [11].

4 Conclusion

AC susceptibility measurements on MPMG YBCO samples, with and without inter-grain coupling, were carried out at various frequencies and applied AC magnetic fields. The effect of Y_2O_3 excess has been investigated. Low AC fields were used so as not to drive the material to the mixed state. Beside Y_2O_3 powder promotes the grain growth and prevents pouring out of liquid phase, Y_2O_3 buffer layer freely poured increases pinning force according to being pressed because of using a seeding source for 211.

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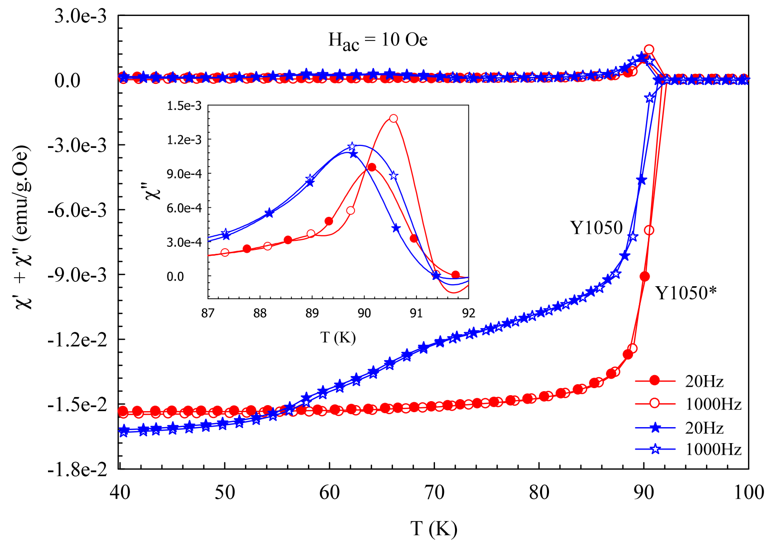

Fig. 5 Plot of (a) real (χ') and (b) imaginary (χ'') components of AC susceptibility as a function of temperature of Y1050* and Y1050 taken at applied ac field amplitude H_{ac} 10 Oe, at different frequencies

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