Physica C 153-155 (1988) 1533-1534
North-Holland, Amsterdam

MAGNETIC ENERGY ABSORPTION IN SINTERED $YBa_2Cu_3O_{7-\delta}$ SAMPLES

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A.c. magnetic susceptibility measurements of eight microscopically characterized sintered $YBa_2Cu_3O_{7-\delta}$ samples are reported. The samples show losses $0.2 > 4\pi\chi'' > 0.002$. χ'' *vs* χ' plots derived for all samples agree with models and results where flux pinning plays an important role.

1. INTRODUCTION

Low field a.c. magnetic susceptibility, $\chi=\chi'-i\chi''$ is a good probe to study granular superconductivity. Reported $\chi(T)$ data for high T_c superconductors in sintered and powdered samples show special features clearly related with the microestructure (1). To investigate the influence of preparation and sintering techniques on the diamagnetic response of $YBa_2Cu_3O_{7-\delta}$, systematic measurements of a series of sintered samples obtained by different methods have been performed.

2. EXPERIMENTAL

Preparation method and other relevant parameters are presented in Table 1. $\chi(T)$ measurements were performed in an automated susceptometer. Samples were cut into bars and oriented parallel to the applied field, 1 mOe < h_0 < 11 Oe, ν=120 Hz.

3. RESULTS AND DISCUSSION

For samples I to VII, the onset of diamagnetism, h_0 independent, starts at T_0, where the resistive transition, $T_0(\rho)$, does too. The strong decrease in χ' takes place at $T_1=T_c(\rho=0)$. At low temperature and low applied field the apparent volume susceptibility corrected from demagnetizing effects reaches an asymptotic value within 10% of perfect flux exclusion. At T_1 a strongly field amplitude dependent peak in χ'' accompanies the transition (2). Sample VII shows a second peak in $\chi''(T)$ at T_0. $\chi'(T)$ and $\chi''(T)$ curves for sample I and h_0=110 mOe are given in figure 1. From inspection of table 1 the trend of increasing hysteresis losses for smaller grain size is apparent.

For sample VIII no anomaly is observed in χ' at T_c=91.8 K. The lowest value of $-4\pi\chi'$ yields only 45% of the ideal one, and it is h_0 independent. χ'' values for h_0=110 mOe are negligible but a sharp peak appears at T_0 for h_0=11 Oe (see inset of figure 1).

Since for ceramic superconductors no frequency dependence exists (3), results will be discussed assuming that magnetic energy absorption is due to hysteresis in the M-H curve of a type II superconductor. Collected results are presented in a χ'' *vs* χ' diagram (figure 2).

3.1. The weak-links model

The sample is considered as an array of superconducting grains connected by weak-links. It can be approximated by an equivalent superconducting loop with a well defined transition temperature, $T_{c1}=T_1$, and a critical current J_{c1} which shows a temperature behaviour depending on the type of weak-links considered (3). All experimental diagrams lay below the theoretical

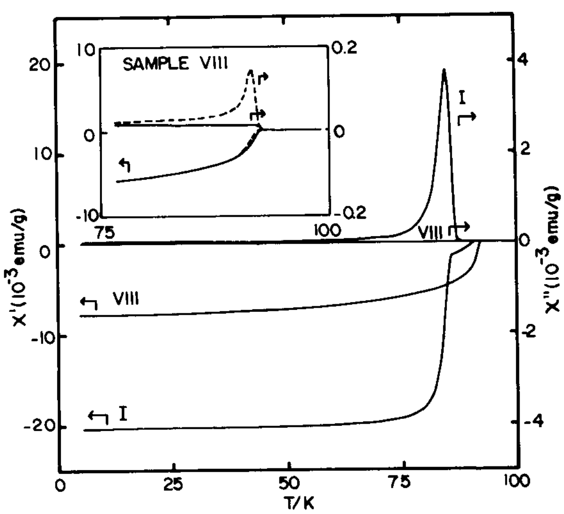

FIGURE 1
χ' and χ'' curves for samples I and VIII, ν=120 Hz, h_0=110 mOe (full line);11 Oe (dashed line). The inset shows enlarged area for sample VIII.

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TABLE 1: Relevant parameters of the eight sintered samples

SAMPLE	PREPARATION METHOD	X-RAY IMPURITIES	GRAIN SIZE (μm)	$T_0(\chi')$	$T_1(\chi')$	$4\pi\chi''_{max}$
I	Liquid mix (7)	Y_2BaCuO_5, $BaCuO_2$	3-5	90,5 K	85,7 K	0.190
II	Solid state reaction (2)	Y_2BaCuO_5	Inhomogeneous	88,0	75,0	0.150
III	Solid state reaction	Y_2BaCuO_5	3-10	88,5	88,5	0.110
IV	Metallorganic precursor(8)		3	87,7	84,2	0.110
V	Citrate route (9)		10-100	91,5	85,0	0.060
VI	Solid state reaction	-	3-10	88,4	84,1	0.060
VII	Citrate route (9)	Y_2BaCuO_5	10-100	91,9	85,0	0.060
VIII	Solid state reaction (10)		0.5 and Crystallites	92,5	--	0.002

curve a in figure 2, probably due to rounding effects in the magnetic hysteresis loop. These could be due to the existence of many weak loops with a random distribution of transition temperatures and critical currents centered at T_{c1} and J_{c1}. The existence of two peaks in χ'' of sample VII could be explained as caused by random distributions centered at (T_{c1}, J_{c1}) and (T_{c2}=T_0, J_{c2}) respectively.

The zero offset on the experimental χ''-χ' diagrams reflects that for samples I to VII $T_1 < T_0$. This may be understood if a transition from a paracoherent state of superconducting grains, with transition temperature T_0, to a coherent state of weakly connected grains occurs at T_1=T_c (4).

The negligible field dependence and the absence of anomaly in $\chi'(T)$ for sample VIII yields the conclusion that electrical connectivity has not weak-link nature, the

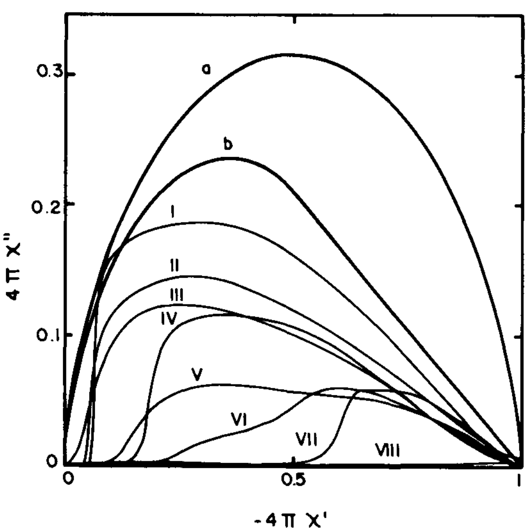

FIGURE 2
χ'' *vs* χ' diagrams for samples I to VIII. Curve a: Weak-links single loop model. Curve b: simplest bulk pinning case of the critical field model.

shielding effect being not so efficient as in the other samples. The very small grains of average size 0.5 μm and crystallites of 10 μm × 5 μm may be responsible of the observed behaviour. Following the model proposed in (3) we conclude that specimen I is a good example of weakly coupled grains, while specimen VIII shows mainly bulk effects.

3.2. The critical field model

In a type II superconductor hysteresis losses can be due to flux penetration subject to pinning forces, when h_0 exceeds the lower critical field. Curve b, figure 2, corresponds to a prediction for the bulk pinning case (5). Flux pinning at low fields in the ceramic superconductors has been evidenced from magnetic hysteresis loop measurements (4).

χ'' *vs* χ'curves for samples I to III agree qualitatively with the model. If pinning is considered weaker in the surface layer than in the bulk core, lower hysteresis losses are expected (5), in agreement with IV-VIII curves. Finally, the existence for some of the samples of two peaks in $\chi''(T)$ has been already explained as caused by two superconducting components with different critical fields (6).

ACKNOWLEDGEMENTS
The financial support of the Spanish C.A.I.C.Y.T. is acknowledged (grant 3380/83).

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