MAGNETIC ENERGY ABSORPTION IN SINTERED YBa2Cu3O7-δ SAMPLES


A.c. magnetic susceptibility measurements of eight microscopically characterized sintered YBa2Cu3O7-δ samples are reported. The samples show losses 0.2 > 4πχ" > 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, χ=χ'+iχ" is a good probe to study granular superconductivity. Reported χ(T) data for high Tc superconductors in sintered and powdered samples show special features clearly related with the microstructure (1). To investigate the influence of preparation and sintering techniques on the diamagnetic response of YBa2Cu3O7-δ, 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. χ(T) measurements were performed in an automated susceptometer. Samples were cut into bars and oriented parallel to the applied field, 1 mOe < h0 < 110e, v=120 Hz.

3. RESULTS AND DISCUSSION
For samples I to VII, the onset of diamagnetism, h0 independent, starts at T0, where the resistive transition, T0(ρ), does too. The strong decrease in χ' takes place at T1=Tc(ρ=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 T1 a strongly field amplitude dependent peak in χ" accompanies the transition (2). Sample VII shows a second peak in χ"(T) at T0. χ'(T) and χ"(T) curves for sample I and h0=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 Tc=91.8 K. The lowest value of 4πχ" yields only 45% of the ideal one and it is h0 independent. χ" values for h0=110 mOe are negligible but a sharp peak appears at T0 for h0=110 e (see inset of figure 1).

FIGURE 1
χ' and χ" curves for samples I and VIII, v=120 Hz, h0=110 mOe (full line);11 e (dashed line). The inset shows enlarged area for sample VIII.

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, Tc=T1, and a critical current Jc which shows a temperature behaviour depending on the type of weak-links considered (3).

All experimental diagrams lay below the theoretical...
TABLE 1: Relevant parameters of the eight sintered samples

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>PREPARATION METHOD</th>
<th>X-RAY IMPURITIES</th>
<th>GRAIN SIZE (µm)</th>
<th>(T_0(x'))</th>
<th>(T_1(x'))</th>
<th>4(\pi x_{\text{max}}^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Liquid mix (7)</td>
<td>Y_2BaCuO_5, BaCuO_2</td>
<td>3-5</td>
<td>90.5 K</td>
<td>85.7 K</td>
<td>0.190</td>
</tr>
<tr>
<td>II</td>
<td>Solid state reaction (2)</td>
<td>Y_2BaCuO_5</td>
<td>Inhomogeneous</td>
<td>88.0</td>
<td>75.0</td>
<td>0.150</td>
</tr>
<tr>
<td>III</td>
<td>Solid state reaction</td>
<td>Y_2BaCuO_5</td>
<td>3-10</td>
<td>88.5</td>
<td>88.5</td>
<td>0.110</td>
</tr>
<tr>
<td>IV</td>
<td>Metallocrinc precursor(8)</td>
<td>3</td>
<td>87.7</td>
<td>84.2</td>
<td>0.110</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Citrate route (9)</td>
<td>10-100</td>
<td>91.5</td>
<td>85.0</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Solid state reaction</td>
<td>3-10</td>
<td>88.4</td>
<td>84.1</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>Citrate route (9)</td>
<td>Y_2BaCuO_5</td>
<td>10-100</td>
<td>91.9</td>
<td>85.0</td>
<td>0.060</td>
</tr>
<tr>
<td>VIII</td>
<td>Solid state reaction (10)</td>
<td>0.5 and Crystallites</td>
<td>92.5</td>
<td>--</td>
<td>0.002</td>
<td></td>
</tr>
</tbody>
</table>

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 \(T_1\) and \(J_1\). The existence of two peaks in \(x''\) of sample VII could be explained as caused by random distributions centered at \((T_1, J_1)\) and \((T_2=J_0, J_2)\) respectively.

The zero offset on the experimental \(x''-x'\) diagrams reflects that for samples I to VII \(T_1 < T_0\). This may be understood if a transition from a para-coherent 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 \(x'(T)\) for sample VIII yields the conclusion that electrical connectivity has not weak-link nature, the 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 x 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).

\(x''\) vs \(x'\) 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 \(x''(T)\) has been already explained as caused by two superconducting components with different critical fields (6).

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