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MAGNETIC PROPERTIES OF \( \text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_x \) SUPERCONDUCTOR OBTAINED BY RAPID QUenchING FROM THE MELT

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Abstract. - High-T\( _c \) \( \text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_x \) superconductor has been produced by rapid quenching from the melt. Low field ac and dc magnetic properties have been measured and are discussed in relation to the microstructure of the material. From the lossy component of the ac susceptibility we have computed the transport critical current and its temperature dependence. From galvanomagnetic studies the effective carrier concentration and Hall mobilities are found to be \( 8 \times 10^{21} \) holes/cm\(^3\) and 0.20 cm\(^2\)/Vs respectively.

Different methods of preparing ductile high-\( T_c \) superconductive materials are of considerable technological significance. Rapid quenching from the melt is potentially one such method [1-4]. This technique provides us with possibilities to control the microstructure and obtain the final phases in a number of ways. For example this method can be considerable compared with conventional sintering because of the ability to obtain high-\( T_c \) superconductors from amorphous, or metastable crystalline precursors. In this brief communication we report the magnetic, electric and transport critical current properties of rapidly melt quenched (RMQ) \( \text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_x \).

Melted droplets from \( \text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_x \) bar, using an oxygen-acetylene flame, were rapidly solidified (quenching rate about \( 10^5 \) K/s) between two heavy cooper plates. From X-ray analyses the as-quenched samples were found to be in a metastable state, which could not be indexed to the phases reported for this oxide system. This as-quenched material is transformed to orthorhombic \( \text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_x \) by annealing at 930 °C for 3 h and then furnace-cooling it to room temperature in flowing oxygen. No X-ray peaks of possible additional phases are observed. We find that heat treating the sample at temperatures lower than 910 °C never results in single phase material. The "as obtained" material was found to be non-superconducting down to 4.2 K. The annealed single phase sample shows zero resistance at 92 K.

To study the diamagnetic properties of this material, the real \( X' (T) \) and imaginary \( X'' (T) \) components of the ac susceptibility have been measured during warming runs for different ac field amplitudes (24 A/m to 2400 A/m) and frequencies (10 Hz to 1 kHz). A typical set of data for \( X' (T) \) and \( X'' (T) \) for the superconducting sample is shown in figure 1. The geometry of the measured sample was a parallelepiped of 0.3×2.5×6 mm\(^3\), with the field applied along the longer dimension. As observed from \( X' (T) \) data in figure 1, the onset of superconducting transition starts at 92 K. Generally speaking, the temperature and field dependences of both \( X' \) and \( X'' \) are similar to those reported for sintered samples [5, 6]. At the lowest applied field and at low temperatures \( X' \) and \( X'' \) achieve values \(-1 \) and 0 respectively, implying complete diamagnetic shielding and the absence of any losses due to trapped flux. With increasing temperature \(-X' \) decreases in two stages, below \( T_c \), whereas \( X'' \) shows a maximum. At the highest applied field (2 400 A/m) \( X' \) is reduced (\(~45\%\)) and we observe two maximum in the \( X'' (T) \) curve. This "two stage" behaviour can be explained as arising from two contributions to the susceptibility: one of which is intrinsic to the superconducting grains, and other originating from the network that links the grains weakly. In ac susceptibility measurements the applied field amplitude \( H_m \) is smaller than \( H_{c1} \) of the grains, so that transport supercurrents only flow in the

![Fig. 1. - Temperature dependence of the real (X') and imaginary (X'') components of the ac susceptibility at H_m: (A) 24 A/m; (o) 240 A/m; (●) 2 400 A/m.](http://dx.doi.org/10.1051/jphyscol:19888979)
network and surfaces of the grains. Following this idea and based on Kim's critical state model [7], a method to determine the transport critical current density has been developed [8]. Thus, the average transport critical current density $J_c(T)$ is computed from the $X''(T)$ data. Figure 2 shows $J_c(T)$ obtained in this way for the present sample. As shown, the computed $J_c$ varies almost linearly with $T$ and reaches a value of about 1 800 A/cm$^2$ at 4.2 K.

In our approach for computing $J_c$, the local critical current density is related to the local field as $J_c(H_l) = k/(H_0 + H_l)$. Here, $H_l$ is a local field, $k$ and $H_0$ are constants. We define a parameter $p = (2k a)^{1/2}/H_0$, where $2a$ is the sample thickness. For the present melt-quenched YBaCuO sample we obtain $p = 1.4$. It is well known that, for a Josephson-type junction [9], the critical current $I_c$ has a strong field dependence, $\sim k/H$, which corresponds to "infinite $p". Thus, the observed small $p$ corresponds to a weaker field dependence of $J_c$, which means the coupling mechanism should be different from that of Josephson-type.

From dc magnetization hysteresis loop measurement at 4.2 K in magnetic fields up to 12 kA/m, we found that the ratio of the critical current densities determined at 9.6 kA/m and 4.8 kA/m is 0.61, a value which is much larger than the expected value of 0.5 determined for well sintered YBaCuO. This means weaker field dependence of $J_c$ for RMQ-Y$\textsubscript{1}$Ba$\textsubscript{2}$Cu$_3$O$_x$ and is consistent with the field dependence of $J_c$ mentioned above.

In figure 3, we show our Hall effect data obtained by a double ac-technique. The Hall coefficient of YBaCuO is strongly dependent on the oxygen content and the value found on RMQ-sample at room temperature of $7.8 \times 10^{-10}$ m$^3$/As is in good agreement with that found for sintered materials of high oxygen content. From the Hall coefficients combined with resistivity at room temperature we determined the densities of carriers and Hall mobilities to be $8 \times 10^{21}$ holes/cm$^3$ and 0.45 cm$^2$/Vs for RMQ-BiSrCaCu$_2$O$_x$ [4].

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