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SUPERCONDUCTIVITY IN 2-2-3 SYSTEM $Y_2Ba_2Cu_2O_{8+\delta}$

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We have synthesized a new high-Tc 2-2-3 superconductor $Y_2Ba_2Cu_3O_{8+\delta}$ by a special preparation technique and characterized it by ac-susceptibility measurements. Diamagnetism and Meissner effect sets in at low fields and superconducting transition onsets at 90 K. The systematic investigation of the real and imaginary components of ac-susceptibility as a function of temperature and applied ac magnetic field reveals that the magnetic behaviour is that of granular-type superconductor.

INTRODUCTION

In general, in the high-Tc granular bulk superconductors it is necessary to distinguish between the superconducting properties of unconnected "grains" and the "bulk" of grains connected through Josephson junctions. AC susceptibility measurements as a function of temperature and magnetic field allow observation of this double behaviour.

No attempt has been made to synthesize and observe superconductivity in 2-2-3 type systems except for our most recent communication (1) of superconductivity in a new 2-2-3 type system $Y_2Ba_{1.5}Ca_{0.5}Cu_3O_{8+\delta}$ by ac-susceptibility and resistivity measurements. In this paper, we report the synthesis and the characterization of another new 2-2-3 superconductor $Y_2Ba_2Cu_3O_{8+\delta}$. Superconductivity in $Y_2Ba_2Cu_3O_{8+\delta}$ (2-2-3) was identified by the systematic measurements of the real and imaginary (lossy) components of ac-susceptibility as a function of temperature and applied ac field.

EXPERIMENTAL

Samples of nominal composition $Y_2Ba_2Cu_3O_{8+\delta}$ were prepared from the appropriate amounts of the finely ground mixed Y_2O_3, $BaCO_3$ and CuO (all 99.9% purity). The mixed powders were pressed into pellets of 1-cm diameter and .2-cm thickness under a pressure of 25 KPSi. We have devised a special technique of sample preparation known as rapid thermal processing (RTP) treatment which is described in detail elsewhere (2). According to this technique 2-2-3 pellets were introduced in a preheated furnace at 950°C and fired for two hours in closed condition. Then the top of the furnace was opened to air for half an hour at 950°C and the samples were rapidly cooled to room temperature. The cooled samples were recycled once more as above. Thus, 2-2-3 samples require two-step processing.

X-ray diffraction data were obtained at room temperature using a Philips PW1820 powder diffractometer with FeKα radiation. X-ray diffraction (Fig. 2) showed single phase for 2-2-3 samples. The real (X') and imaginary (X") components of the ac-susceptibility of a sintered $Y_2Ba_2Cu_3O_{8+\delta}$ were measured as a function of temperature (4.2K to 128K) for different ac field amplitudes (24A/m to 2400A/m or 0.3 Oe to 30 Oe) at a frequency of 100Hz. In these measurements the samples were first zero-field cooled to liquid helium temperature and then measured in applied ac fields during the warming run.

RESULTS AND DISCUSSION

All observed X-ray powder diffraction peaks of $Y_2Ba_2Cu_3O_{8+\delta}$ can be accounted for by an orthorhombic unit cell of a=4.0314 (11) Å, B=3.7202 (8) Å and c=13.338 (5) Å crystallographically. The observed X-ray diffraction pattern of this new superconducting compound is compared with the corresponding computer X-ray diffraction spectra obtained employing the refined unit cell constants and the atomic fractional coordinates assuming space group symmetry Pmmm. A very good agreement is found between the observed and computed X-ray spectra confirming that the atomic arrangement is of a simple perovskite-type belonging to the orthorhombic Pmmm space group. From a comparison of lattice parameters of 1-2-3 (3.4) with the present 2-2-3, it is evident that a and c parameters have respectively increased by 0.21 Å and 1.68 Å. Moreover, the unit cell volume of 1-2-3 is 173.7 $Å^3$ (3.4) and that of 2-2-3 is 200.2 $Å^3$. These observations indicate that the excess "Y" in 2-2-3 is responsible for the expansion of the unit cell and possibly additional "Y" is located along the c axis. The temperature dependence of both the real (X') and imaginary (X") of the ac-susceptibility data measured at 100Hz and in applied ac fields 0.3 Oe, 3.0 Oe and 30.0 Oe is shown in Fig. 2. As observed from X'(T) data in Fig. 2, the sample $Y_2Ba_2Cu_3O_{8+\delta}$ exhibits diamagnetism and Meissner effect at low field 0.3 Oe, and the onset of superconducting transition starts at 90K. For a perfect superconducting state, at the lowest applied field and at low temperatures, X' and X" should attain values of -1 and 0, respectively, implying complete diamagnetic shielding and the absence of any losses due to the trapped flux.

In the present case, at 0.3 Oe (low field) and at 4.2K (low temperature), X' and X" achieve values of -0.92 and 0.007, respectively, implying 92% diamagnetic shielding and slight imperfect diamagnetism below Tc. With increasing temperature at 0.3 Oe, X' changes from -0.92 below Tc to a small positive value above Tc, while the imaginary part, X" , peaks at Tc and is practically zero above and below Tc. Both X' (T) and X" (T) are sensitive to the ac-applied fields and thus can give significant insight into the role of microstructure on the superconducting properties of these new high-Tc oxide sintered materials.

It is evident from Fig. 1 that as the ac-applied field is increased to 240 A/m (eOe), X' reduces to 85% diamagnetic shielding, while the X" exhibits a slight peak at Tc in addition to a major broadened peak at about 40K. These features indicate two contributions to the susceptibility of the material; one very sensitive to measuring field and the other, relatively insensitive to field (5,6). On the other hand, for moderate fields like 0.3 Oe (Fig. 1), the two contributions to the susceptibility are not separable or it is sufficient to supress one of the contributions near Tc at this field. These observations suggest that the investigation of the magnetic field dependence of ac susceptibility is a particularly useful method for separating the two contributions. Further increase in ac-applied field to 2400 A/m (30 Oe), X' reduces to 45% diamagnetic shielding and X" again shows a peak near Tc along with very broad indication of peak. Also note that the lossy component X" which should ideally be zero for the superconducting state is rather large and positive at liquid helium temperature at fields above 3 Oe. This is unusual if the material was indeed a bulk superconductor. These observations indicate that a significant amount of flux indeed penetrates through the system even at low fields, and that in fields above 30 Oe, one essentially is looking at the intra-granular superconducting properties. The "two-stage" ac-susceptibility behaviour can be explained as arising from two contributions to the susceptibility; one of which is intrinsic to the superconducting grains, and the other originating from the network that links the grains weakly.

In conclusion, we have prepared and identified a new high-Tc superconductor $Y_2Ba_2Cu_3O_{8+\delta}$ (2-2-3) by ac-susceptibility measurements. The systematic investigation of the real and imaginary components of ac-susceptibility as a function of temperature, applied field and frequency reveals that the magnetic behaviour is that of a granular-type superconductor in which "strongly" superconducting grains are coupled via weak superconducting links.

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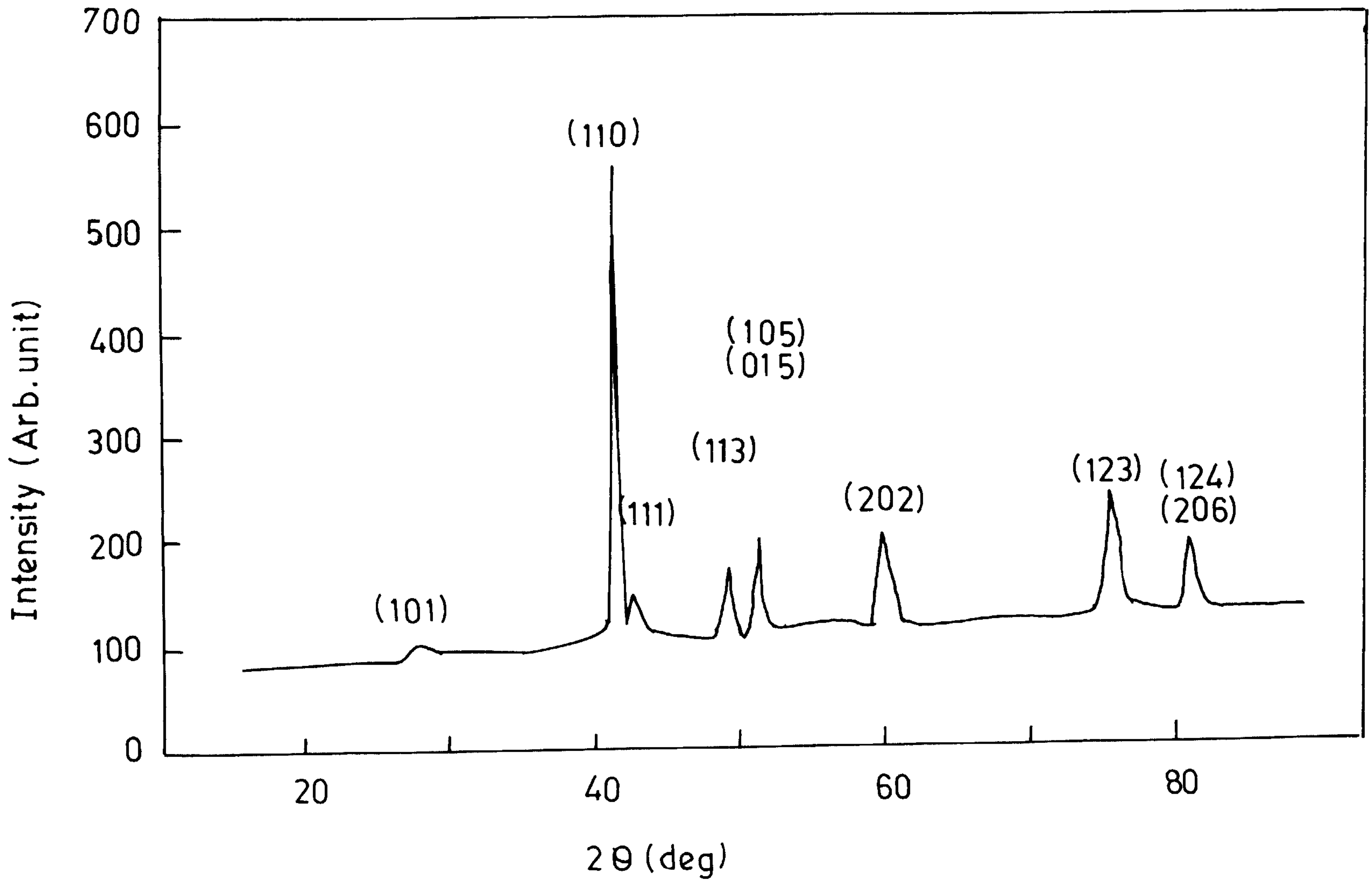

Figure 1. X-ray data for $Y_2Ba_2Cu_3O_{8+\delta}$.

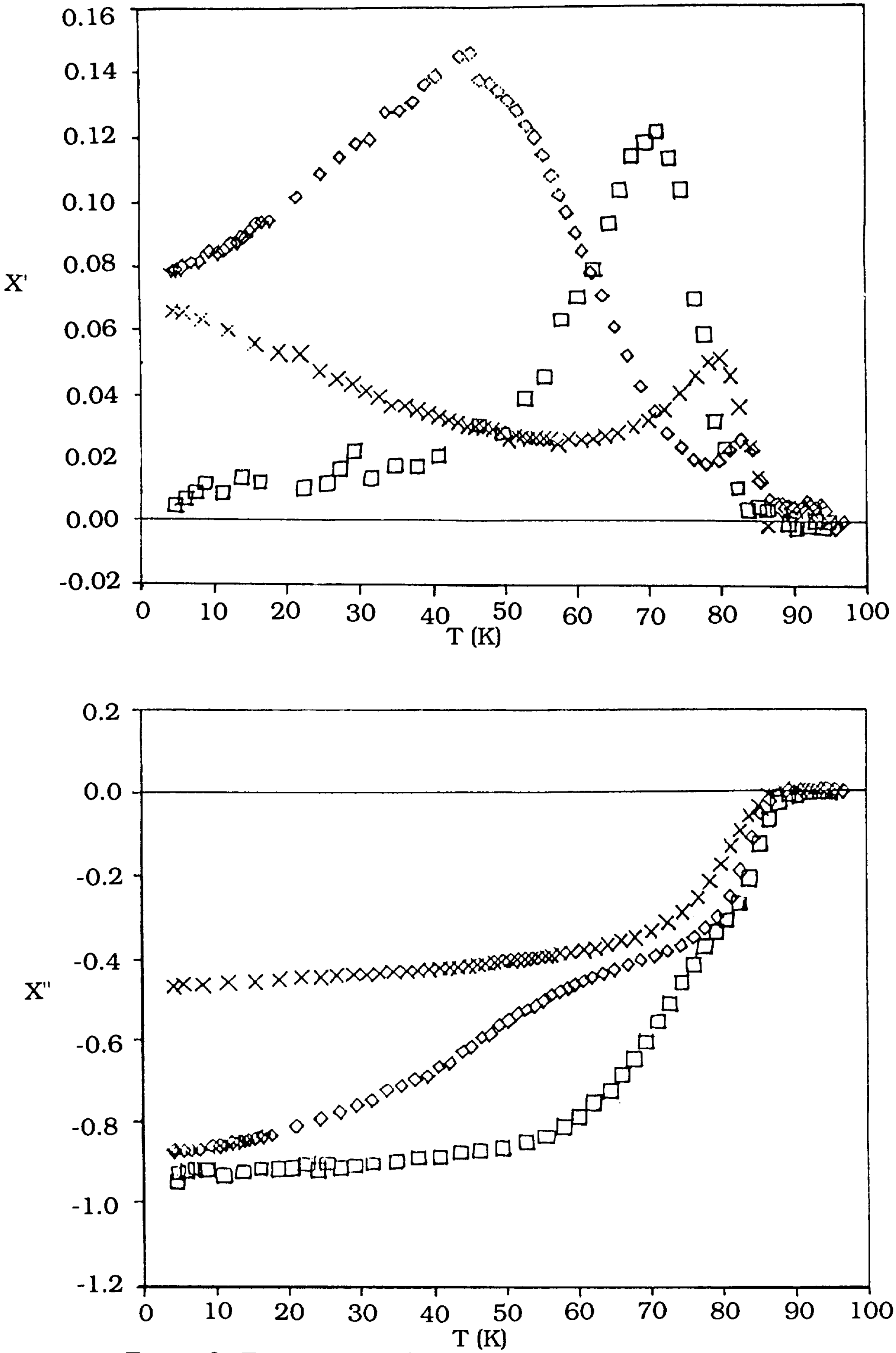

Figure 2. Temperature dependence of the real (X') and imaginary (X'') components of the ac-susceptibility of $Y_2Ba_2Ca_3O_{8+\delta}$ at 24 A/m (□); 240 A/m (◇); and 2400 A/m (X).