

## ONSET OF SUPERCONDUCTIVITY IN Y-Ba-Cu-O AT 100 K

L.C. BOURNE <sup>a</sup>, Marvin L. COHEN <sup>a,b</sup>, William N. CREAGER <sup>a</sup>, Michael F. CROMMIE <sup>a</sup>,  
Angelica M. STACY <sup>b,c</sup> and A. ZETTL <sup>a</sup>

<sup>a</sup> Department of Physics, University of California, Berkeley, CA 94720, USA

<sup>b</sup> Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA

<sup>c</sup> Department of Chemistry, University of California, Berkeley, CA 94720, USA

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Resistive and magnetic measurements on Y-Ba-Cu-O samples indicate transitions to the superconducting state beginning near 100 K with transition widths typically around 15 K.

The recent breakthrough in achieving high temperature superconductivity in the La-Ba-Cu-O system by Bednorz and Müller [1] has motivated further studies [2-6] of superconductivity in this system and in similar solids having Sr and Ca replacing the Ba. The results [5] for  $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$  for  $x=0.2$  are representative; these samples exhibit superconductivity at 36.2 K with a width of 1.4 K in electrical resistivity measurements. Furthermore, magnetic measurements indicate that 60%-70% of the bulk sample is superconducting.

Two important features of the superconducting transitions are the sensitivity of the transition temperature  $T_c$  to pressure and to the substitution of Sr and Ca for Ba. The onset temperature  $T_c^0$  was found [4] to increase from 32 to 40.2 K at 13 kbar at a rate of  $\sim 0.9$  K/kbar. The onset and final transition temperatures  $T_c^f$  were shown [7] recently to increase from 39 to 52.5 K and from 20 to 25 K, respectively, under a hydrostatic pressure of 12 kbar. The matching of  $\text{Sr}^{2+}$  and  $\text{La}^{3+}$  ion sizes [8] appears to produce well behaved La-Sr-Cu-O samples with high  $T_c$ 's and narrow widths. When Ca is substituted for La,  $T_c$  decreases. The  $T_c$ 's for the Ba samples generally lie between the two broad transitions, but sometimes the  $T_c^0$  are higher.

The influence of the mismatch in ion sizes and the strong pressure dependence of  $T_c$  suggest that the electrons near the Fermi energy are affected by these changes in the lattice. This motivated our investiga-

tion of the  $\text{Y}_{2-x}\text{Ba}_x\text{CuO}_4$  system. Motivation was also provided by reports in the popular press of superconductivity in samples of undisclosed composition by C.W. Chu and collaborators.

We have prepared polycrystalline samples of  $\text{Y}_{2-x}\text{Ba}_x\text{CuO}_4$  by reacting  $\text{Y}_2\text{O}_3$ ,  $\text{BaCO}_3$ , and  $\text{CuO}$ . Finely ground powders of the starting materials were pressed into a pellet and sintered in an oxygen atmosphere at 1082°C. A series of samples with  $x$  ranging from  $x=0$  to  $x=0.9$  was investigated <sup>11</sup>.

Fig. 1 shows the dc resistance as a function of temperature for two samples with  $x \approx 0.8$ . The resistance decreases linearly with temperature for sample A until  $T_c^0 \approx 100$  K where it deviates from its high temperature behavior and then falls dramatically with decreasing temperature. Sample B shows a slightly rising resistance with decreasing temperature until 90 K where it drops abruptly with a transition width (90% to 10%) of 15 K. The resistance is low at 57 K and zero below 37 K. We have further investigated the superconducting transition region by resistivity measurements in the presence of a magnetic field. Above  $T_c^0$ , no  $H$  dependence of resistance was observed, while at the midpoint of the transition a 0.3 kG field increased the resistance by approximately 3.0%.

<sup>11</sup> Although the combined radii of YBa are about the same as LaSr, at this point we do not know whether our samples are in the same structural phase as the La-based materials.

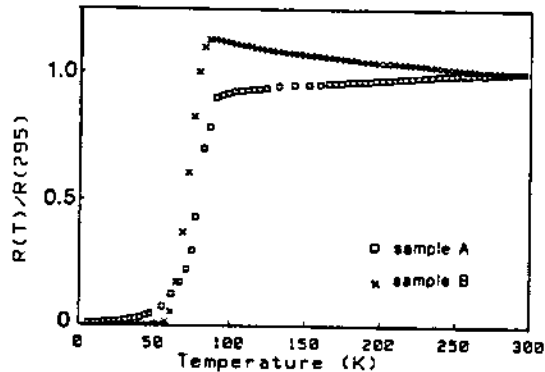


Fig. 1. Resistance versus temperature for two samples of  $Y_{1.2}Ba_{0.8}CuO_4$ .

The susceptibility  $\chi_g$  for an  $x \approx 0.8$  sample from the same preparation batch as sample B in fig. 1 is given in fig. 2 as a function of temperature. The latter measurements were made using a SQUID magnetometer with the sample cooled in a 12 gauss field. The results indicate that a large fraction of the sample is contributing to the shielding. The samples are inhomogeneous and we observe evidence of trapped flux. In some Y-Ba-Cu-O samples, we have observed resistive fluctuations to lower resistance states at temperatures as high as 234 K. However, the results are not consistently observed, even for a given sample. The observations may be the result of inhomogeneous current distributions and unusual contact

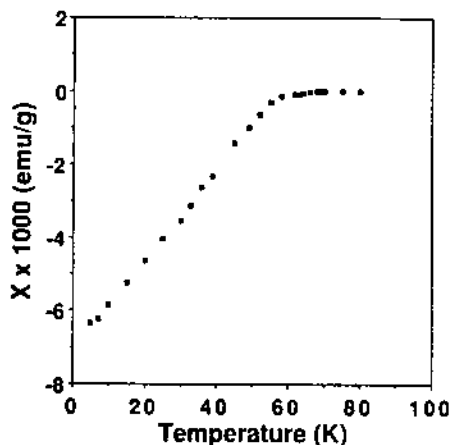


Fig. 2. Magnetic susceptibility of  $Y_{1.2}Ba_{0.8}CuO_4$  versus temperature.

effects in these highly non-uniform materials.

There have been a number of theoretical suggestions attempting to explain the high superconducting transition temperatures of the La-based oxides. The increase in  $T_c$  for the Y-based samples gives further motivation for theoretical study. Band structure calculations [9,10] for La-based solids indicate that the Fermi level lies in a band composed of Cu 3d and O 2p states with principal contributions coming from antibonding  $d(x^2-y^2)$  and  $p(x, y)$  orbitals in the layer  $xy$  plane. Based on this electronic structure model, it has been suggested [9,10] that conventional electron-phonon BCS superconductivity is dominant in the La-based materials. Further support for a view of this kind is given [11] by an electron-phonon calculation of the Eliashberg-McMillan function  $\alpha^2(\omega)F(\omega)$  and the electron-phonon coupling parameter  $\lambda$ . Strong electron-phonon coupling to O vibrations leads to  $\lambda \geq 2$  and  $T_c$ 's of around 30–40 K. Although this study [11] does not suggest  $T_c$ 's in the range observed by us in the Y-based materials, differences in the lattice and electronic structure could change the electron-phonon and Coulomb interaction parameters to accommodate the high  $T_c$ 's with the BCS electron-phonon theory.

Other mechanisms have been suggested including excitonic [12], 2-D plasmons [13], a resonating valence bond state [14], and excitonic negative-U centers [15]. At this point the observations of the very high  $T_c$ 's in the Y-based samples do not rule out any of these properties. However, it will be important to determine whether the Y-based samples do contain two-dimensional structural units since some of the theoretical mechanisms are based on this feature.

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