Superconductivity in bulk and film ceramics Bi–Sr–Ca–Cu–O

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(Submitted 4 April 1988)
Pis'ma Zh. Eksp. Teor. Fiz. **48**, No. 1, 19–20 (10 July 1988)

A superconducting transition with $T_{c0} = 82$–95 K and T_c $(R = 0) = 82$–72 K has been detected in bulk and film samples of $Bi(Sr_{1-x}Ca_x)_2Cu_3O_y$ synthesized in a solid-phase reaction. The resistance, critical current, and susceptibility were measured as a function of temperature.

In view of the urgent problem of compiling an extensive list of high-temperature superconducting compounds, we have studied the system[1] $Bi(Sr_{1-x}Ca_x)_2Cu_3O_y$. We synthesized bulk ceramic samples of the indicated composition with $x = 0.0$–1.0. As the starting components we used powders of $Bi_2O_3(Bi)$, SrO, CaO, and CuO. The mixture of these powders was pressed into pellets (of 3 mm height and 10 mm in diameter) which were heated to a temperature of $\approx$850–950 °C for $\approx$2 h and then cooled slowly ($\approx$10–12 h) to room temperature. As a result of this single-step procedure, we obtained black, externally homogeneous samples of various densities. During sintering of the samples, the diameter of the samples which were synthesized from Bi increased.

As contacts we used deposited In–Ga pads and clamped probes. The resistance $R(T)$ was measured by the direct- and variable-current four-probe method. The magnetic susceptibility $\chi(T)$ was measured on the basis of the resonant bridge scheme.

Figures 1 and 2 show the $R(T)$ and $\chi(T)$ curves for the compositions under study. Table I gives the characteristic resistive temperature points.

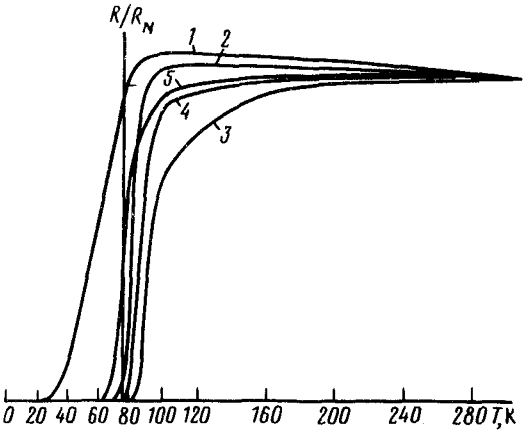

FIG. 1. Resistance vs temperature curves. 1—$x=0$, $R_N=150$ mΩ; 2—$x=0.1$, $R_N=50$ mΩ; 3—$x=0.2$, $R_N=30$ mΩ; 4—$x=0.5$, $R_N=25$ mΩ; 5—$x=0.8$, $R_N=200$ mΩ.

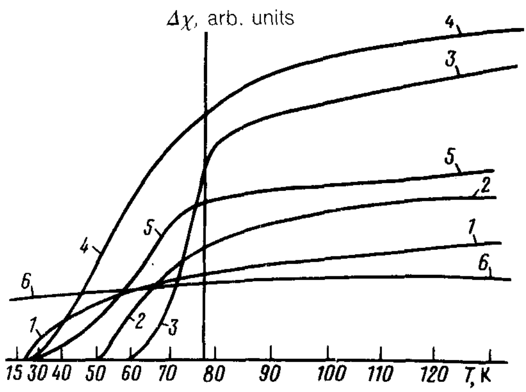

FIG. 2. Variation of the magnetic susceptibility vs temperature. 1—$x=0$; 2—$x=0.1$; 3—$x=0.2$; 4—$x=0.5$; 5—$x=0.8$; 6—$x=0.9$, 1.0.

We see that the satisfactory characteristics fall within a broad interval of compositions, $x=0.1$–0.7, the best being that with $x \approx 0.2$.

Magnetic susceptibility estimates show that the fraction of the superconducting phase in the bulk ceramic samples amount to 10–20% and reaches the peak value at

TABLE I. Resistive temperature points ($T_{c0}, T_{c1/2}, T_{cf}, \Delta T$): the beginning, midpoint, end, and width (10–90%) of the transition.

x	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
T_{c0}	72	96	96	92	90	90	88	87	82	Absence of superconductivity	
$T_c^{1/2}$	55	87	90	84	83	86	82	81	76		
T_{cf}	35	77	84	77	77	78	76	75	70		
ΔT	28	16	9	12	10	9	10	10	10		

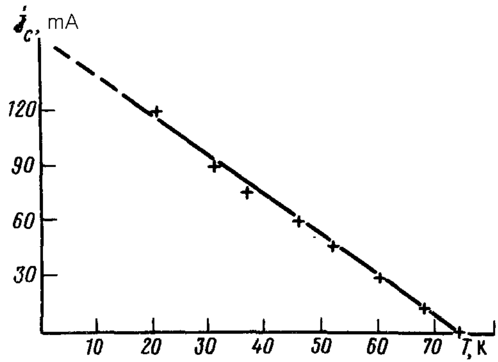

FIG. 3.

$x \approx 0.2$. The superconducting ceramic films with $x = 0.5$ and $x = 0.25$ were obtained on sapphire substrates. The ceramic films were fabricated by raising the temperature of the powder mixture slightly above the melting point ($\approx$900–950 °C). These films, $\approx$200–250 μm thick, have a black, shiny surface.

An important point here is that large crystallites with dimensions $\gtrsim 1$ mm can be formed on the surface as a result of slow cooling.

We measured the temperature dependences of the resistance $R(T)$ of the ceramic films for several values of the current and $\chi(T)$. We found the typical $T_{c1/2}$ to be 77 K. With an increase in the current, T_c decreases. The temperature dependence of the critical current is shown in Fig. 3. At 4 K the critical current density is $j_c \approx 25$ A/cm^2. The volume of the superconducting phase (the estimate is based on the inductive signal) is $\approx$40–50%.

Future experimental studies will be directed toward the optimization of the compositions, improving the thermal treatment of the samples and expanding the nomenclatures of the ceramic film substrate.

[1]C. Michel *et al.*, Z. Phys. **B68**, 420 (1987).

Translated by S. J. Amoretty