SUPERCONDUCTIVITY IN Bi-Pb-Ca-Sr-Cu-O THIN FILMS

S.M.FU*, H.C.YANG, F.C.CHEN, H.E.HORNG†, and J.C.JAO

Department of Physics, National Taiwan University, Taipei, Taiwan, R.O.C.

*Ming Hsin Engineering College, Hsin-Chu, Taiwan, R.O.C.

†Department of Physics, National Taiwan Normal University, Taipei, Taiwan, R.O.C.

Thin films of Bi-Pb-Ca-Sr-Cu-O sample were prepared by RF sputtering from sintered ceramic targets. Single crystal of MgO(100) was selected as substrate. The sputtering was held at room temperature. Different annealing conditions were carried out to obtain optimum conditions. High temperature resistivity was measured in air to study the thermodynamic reaction of the sintered films. An resistivity anomaly was found in the first heating cycle which suggests a thermodynamic reaction. A temperature dependence of I_c was measured to study the coupling of grains in the granular films in different temperature ranges and the results will be discussed.

Recently a new class of superconducting compound, the Bi-Ca-Sr-Cu-O system^{1,2} was found with transition temperature ranging from 80 K to 105 K. The nominal transition at 80 K has been attributed to the phase $\text{Bi}_2\text{CaSr}_2\text{Cu}_2\text{O}_y$. Ichikawa et al³ have reported thin films of Bi-Ca-Sr-Cu-O. In this paper, we report the superconductivity, critical current and high temperature resistance behavior of Bi-Pb-Ca-Sr-Cu-O thin films.

Two ceramic targets were used in the magnetron sputtering system. Target A is $\text{Bi}_2\text{Pb}_{0.3}\text{Ca}_{2.2}\text{Sr}_2\text{Cu}_{3.2}\text{O}_y$ and target E is $\text{Bi}_2\text{Pb}_{2.3}\text{Ca}_3\text{Sr}_{2.5}\text{Cu}_{3.2}\text{O}_y$. Powders of Bi_2O_3 , CaCO_3 , SrCO_3 and CuO were sintered in air at 820°C for about 12 h. The annealed powder was reground, pressed into a target and sintered in air at 850°C for another 24 h. The sputtering conditions were reported previously.⁴ MgO(100) single crystals were selected as substrate. Table I shows data for various samples. All samples were subjected to a rapid heating and a rapid quenching process.

Figure 1 shows the resistance as a function of temperature for sample 62a. A sharp superconducting transition and a strong metallic behavior in resistance were found. The transition temperature (T_c 50% resistive) is at

FIGURE 1
Resistance as a function of temperature for samples 62a.

TABLE I
The annealing conditions, room temperature resistance and superconducting transition temperature $T_c(R=0)$.

Sample	Annealing temperature (°C)	Annealing time (min.)	R(300K) (Ω)	$T_c(R=0)$ (K)
48a	850	240	22	57
50d	860	15	80	10
61a	850	180	59	65
62a	850	210	13	78

82 K and a zero resistance is at 77 K. The powder X-ray data show predominately (2:1:2:2) phase with c axis perpendicular to the surface. Other phases are also present.

We have measured the temperature dependence of I_c for most samples. The exponent, b , obtained from fitting the data to $I_c = A(1-t)^b$ (Amp), where $t = T/T_c$ are shown in Table II. The

TABLE II
Critical exponent b derived from fitting the I_c data at T near T_c to $I_c = A(1-t)^b$, where $t = T/T_c$.

Samples	b	A (Amp)	T_c (K)
57c	1.51	0.00621	61
61a	1.99	0.261	75
62a	2.09	8.64	80
62b	2.07	19.8	82

obtained b value varies from 1.5 to 2.0 for the samples reported here. Regarding the study of the critical current of the oxide films, a critical exponent varies from 1.5 to 2.0 were reported⁴⁻⁷. Our present data show different exponents depending on the superconducting properties of the samples. For samples which show a long tailing in resistance the exponent is 1.5 while samples with a sharp superconducting transition the exponent is 2.0.

Figure 2 shows typically the high temperature resistance as a function of temperature for sample 62c. The sample has a $T_c(R=0)$ at 55K. The heating rate was about 5 °C/min. In the heating the resistance increases continuously. A precipitous increase at 475 K was followed by a resistive peak at 520 K. Above 520 K the resistance decreases sharply. As the sample was cooled down from 1000K, the resistance decreases continuously to a room temperature value of 27 Ω . The high temperature resistance anomaly may arise from the followings. (1). A relaxation process, (2). an oxygen loss, or (3). an oxygen related thermodynamic process. Reason (1) is less likely, because in an relaxation process one can only decrease the resistance instead of introducing a peak in the resistance curve. Reason (2) may happen in the heating, however, it is not responsible for the resistivity anomaly because a loss of oxygen can cause an increase in resistivity as in the case of

FIGURE 2
High temperature resistance behavior for sample 62c.

$\text{RbBa}_2\text{Cu}_3\text{O}_{7-y}$.⁸ Therefore, we think it is not the main cause for the resistivity anomaly. Reason (3) may be responsible for the resistivity anomaly because the DTA data in O_2 show an exotherm at the resistivity peak. The resistivity anomaly between $T=470\text{K}$ and 600K in the first heating cycle is similar to that observed in the bulk Bi-Ca-Sr-Cu-O Samples.⁹

In this work, we have studied the superconducting properties of Bi-Pb-Ca-Sr-Cu-O thin films. The resistivity shows an anomaly in heating indicating that a thermodynamic decomposition process has occurred in the sample as confirmed by DTA. The critical exponent obtained from the I_c data at T near T_c varies from 1.5 to 2.0 in the samples. This is consistent with results⁴⁻⁷ reported in high T_c polycrystalline thin films.

REFERENCES

1. H.Maeda et al., Jpn. J. Appl. Phys. (1988) 27.
2. J.M.Tarascon et al., Phys. Rev. B38 (1988) 2504.
3. Y.Ichikawa et al., Phys. Rev. B38 (1988) 765.
4. H.E.Hornig et al., Phys. Rev. B39 (1989) 9628.
5. K.Setsune et al., Appl. Phys. Lett. 53 (1987) 600.
6. J.W.C. de Vries et al., J. Appl. Phys. 64 (1988) 426.
7. C.W.Yuan et al., J. Appl. Phys. 64 (1988) 4091.
8. H.C.Yang et al., Phys. Rev. B39 (1989) 9203.
9. H.C.Yang et al., (Submitted).