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Critical current density and magnetization studies on Bi(Pb)SrCaCuO

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Abstract. High T_c phase ($T_c \sim 110$ K) has been obtained in Bi–Sr–Ca–Cu–O system by partially substituting Bi by Pb. Magnetic hysteresis has been measured as a function of temperature. Critical current densities have been measured at 77 K both by transport and a.c. magnetization method in bulk samples for various concentrations of Pb. The results show that substitution of 15 at% Pb for Bi is most preferable for higher critical current density.

Keywords. Critical current; superconductivity; magnetization measurements.

1. Introduction

Following the discovery of superconductivity in Bi–Sr–Ca–Cu–O system (Michel *et al* 1987; Maeda *et al* 1988), it is well established that the compound exhibits superconductivity in two phases, viz. a high T_c 2223 phase ($T_c \sim 110$ K) and a low T_c 2212 phase ($T_c \sim 80$ K). The two phases are normally found to coexist, so that the zero resistance is attained only below 85 K.

Efforts have been made to stabilize the high T_c (110 K) phase by different methods. Limited success has been obtained (Shi *et al* 1988) in pure compounds to achieve $\rho = 0$ at 110 K. The procedure involves long sintering times and is complicated. An alternative approach (Statt *et al* 1988) is to dope Pb for bismuth which aids the growth of 110 K phase. The latter procedure is more common for its simplicity, but is believed to result in multi-phase samples. In this paper we present our studies on critical current densities and low field magnetization hysteresis in $Bi_{2-x}Pb_xSr_2Ca_2Cu_3O_y$ samples for $0{\cdot}2 \leqslant x \leqslant 0{\cdot}4$.

2. Experimental details and results

Samples were prepared by reaction (Tomy *et al* 1989) of Bi_2O_3, PbO and $Sr_2Ca_2Cu_3O_7$ with two different types of heat treatments. In the first type (referred to as group I), the mixture was calcined in air at 820°C for 2 h, then pelletized and sintered at 855°C for 96 h in air and then slow-cooled. For the other group (referred to as group II), the mixture was first pressed and flashed to 900°C for 5 min for surface-melting followed by sintering at 855°C for 96 h in air and then slow-cooled.

Transport measurements of J_c were made (Malik *et al* 1988) at 77 K from the V–I curve. The results are shown in table 1. We note that J_c value is lower than that obtained in YBaCuO system. A peak in J_c is obtained for $x = 0{\cdot}3$ for both groups of samples without any significant change in T_c.

The hysteresis curves are measured using an AC (317 Hz) susceptibility instrument (Radhakrishnamurthy *et al* 1978) coupled with a flow-type liquid nitrogen cryostat. The sample and a copper constantan thermocouple are encapsulated in a nylon sample holder which is filled with Apiezone N grease. The sample holder rests in a glass tube and its position is adjustable with respect to the secondary coils of the susceptibility instrument. Temperature is varied in the range of $T = 77$ K to 120 K with $\Delta T = \pm 0{\cdot}5$ K by controlling the rate of flow of the nitrogen gas through liquid nitrogen. Samples in the pellet geometry are used in this study. The maximum cycling field, H_{max}, can be varied between 1 Gauss and 10 Gauss. T_c was measured as the temperature of diamagnetic onset with a cycling field $H_{max} = 8$ Gauss. J_c can also be estimated from the remnant magnetization M_r at 77 K in the field of 8 Gauss. The remnant magnetization is indicated schematically in figure 1 and gives a measure of the transport J_c (Shailendra Kumar *et al* 1990). The data obtained from the low field hysteresis are shown in table 2.

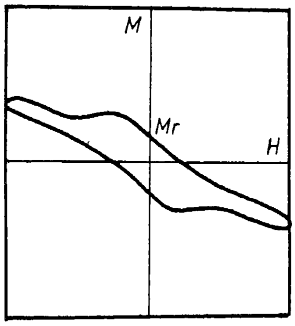

Figure 1. Schematic of hysteresis curve for $H_{max} = 8$ Gauss at 77 K.

Table 1. Transport J_c and T_c of various samples.

x	Gr. I. J_c (amp/cm^2)	T_c(K)	Gr. II. J_c (amp/cm^2)	T_c(K)
0·2	0·70	110	Very small	108
0·3	12·30	110	6·86	110
0·4	1·40	108	3·62	110

Table 2. Remnant magnetization M_r for different concentrations of Pb.

x	Gr. I. $2M_r$ (arbitrary unit)	Gr. II. $2M_r$ (arbitrary unit)
0·2	0·0	1·0
0·3	11·5	4·5
0·4	8·5	2·0

M_r also peaks at $x = 0{\cdot}3$ and this correlates qualitatively with the transport measurement.

3. Conclusion

The transport J_c measured from the V–I curve shows a clear peak at $x = 0{\cdot}3$ irrespective of the preparation route followed, while T_c (as measured from the diamagnetic onset) is unchanged (to within 2 K) as x is varied from 0·2 to 0·4. The stronger intergrain coupling at $x = 0{\cdot}3$ is also reflected in the fact that M_r peaks at $x = 0{\cdot}3$.

The addition of lead helps stabilize the 2223 phase and its concentration is not crucial for high T_c. Our results show that the best intergrain coupling is achieved for $x = 0{\cdot}3$.

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