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Addition of Co_3O_4 to Introduce Pinning Centre in Bi-Sr-Ca-Cu-O/Ag Tapes

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ABSTRACT

This study investigated the flux pinning capability of Co_3O_4 in Bi-Sr-Ca-Cu-O superconductor tapes. The Bi-Sr-Ca-Cu-O powders were prepared by using the co-precipitation technique with the addition of Co_3O_4 as pinning centre to enhance the transport critical current density (J_c) of the system. The Ag sheathed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ (2223) and $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$-$(Co_3O_4)_{0.01}$ high temperature superconductor tapes were fabricated using the powder in tube method. The effects of Co_3O_4 addition on the microstructure, critical temperature and critical current density were studied. The J_c value of the Co_3O_4 added tapes increased to ~4500 A/cm_2. This tape showed the highest J_c and Tc when heated at 845˚C for 50 hours. XRD diffraction pattern showed that the addition of Co_3O_4 inhibits the 2223 phase formation. This study shows that magnetic particles can act as effective pinning centres leading to the enhancement of J_c in the system.

Keywords: Superconductivity, flux pinning, Co_3O_4 addition

INTRODUCTION

Bi-2223/Ag superconductor tape is one of the most promising materials for tape or wire applications. Its poor performance under magnetic fields, which arises from the weak pinning of flux lines, limits its applications (Van Bael *et al.*, 2001) High critical current density J_c is required to meet practical applications. The strong increase of the critical current density J_c, up to the theoretical limit can be achieved when the flux lines are pinned and their movement completely prevented (Aloysius *et al.*, 2005). The flux lines in the solid state could be pinned by introducing effective artificial pinning centers so as to sustain the current density at higher fields and higher temperatures. These studies introduce ferromagnetic impurities as the pinning centers. Magnetic dots are successfully used as artificial pinning arrays in superconducting film covering the dots (Jia *et al.*, 2000).

MATERIALS AND METHODS

Samples with nominal composition $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ (BPSCCO) were prepared using the metal acetates of bismuth, strontium, lead, calcium and cooper (purity ≥ 99.99%), oxalic acid, deionized water and 2-propanol. The coprecipitation method was used in this

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system due to advantages such as good homogeneity, low reaction temperature, and fine and uniform particle size. The co-precipitation precursors were prepared by pouring the solution containing the metal ions into another containing 0.5 M oxalic acid dissolved in deionized water:2-propanol (1:1.5) and uniform, stable, blue suspension was obtained. The slurry was filtered after 5 minutes of reaction time followed by a drying stage at temperatures of 80˚C for 12 hour. The blue precipitate powders were heated up to 730˚C in air to remove remaining volatile materials. The calcined powders were reground and heated again at 845˚C in air for 24 hours followed by cooling at 2˚C /min. After the sintering process Co_3O_4 (300-400 nm) ultrafine particles were added to the composition with $Bi_{1.6}$ $Pb_{0.4}$ $Sr_2Ca_2Cu_3O_\delta$-$(Co_3O_4)_x$ where x = 0.00 and 0.01. The powders were ground and combined with 0.01 wt% Co_3O_4 before being packed into Ag tube with outer diameter of 6.12 mm and inner diameter of 4.43 mm. This wt% was chosen based on our previous study on bulk 2223 samples where 0.01 wt% of Co_3O_4 optimized the superconducting properties of the system (Kilic *et al.*,1998).

The tube was groove rolled, drawn into wire and then flat rolled into tape form. All deformations processed were carried out using a rolling cylinder 20 mm in diameter and rolling speed of about 0.6 m/min. The tapes were cut into 2 cm long sections and divided into six groups. Each group was sintered for 50 hours at different sintering temperatures. The FC 201 sample was sintered at 840°C, FC 111 at 845°C and FC 121 at 850°C sintered for 50 hours. FN 101, FN 111 and FN 121 are tapes without Co_3O_4 addition sintered at various temperatures for 50 hours as summarized in Table 1.

TABLE 1
Sintering temperature, J_c and T_c for tapes samples

Samples	Sintering Temperature (°C)	J_c at 77K A/cm^2	T_c (K)
$Bi_{1.6}$ $Pb_{0.4}$ $Sr_2Ca_2Cu_3O_\delta$			
FN 101	840	2455	78
FN 111	845	3090	78
FN 121	850	2182	80
$Bi_{1.6}$ $Pb_{0.4}$ $Sr_2Ca_2Cu_3O_\delta$-$(Co_3O_4)_{0.01}$			
FC 101	840	3308	88
FC 111	845	4507	93
FC 121	850	2308	97

The transition temperature was determined using the standard four-point probe method contact in conjunction with a closed cycle refrigerator. Transport critical current measurements were done at 77 K using four probe methods with the 1μVcm^{-1} criterion. In this criterion as the current is varied, the voltage (V) across the bar shape sample is measured and the distance between the voltage probes divided. Phase analysis of the samples was done using an XRD (Philips PW 3040/60 X'pert Pro) equipped with a monochromator at the diffracted beam side.

RESULTS AND DISCUSSION

Table 1 shows J_c for different sintering temperatures. It is clearly seen that J_c is strongly correlated with the sintering temperature with optimum value at 845°C.

Fig. 1 displays the effect of sintering temperature on the temperature dependence of critical current density J_c to non addition and addition of Co_3O_4 tape. At low temperature (30 K), J_c values are higher due to thermal activated flux motion becoming zero instead of being pronounced at higher temperature (77 K). It was found that J_c is enhanced in added tape as the size of the grains is decreased. This is an indication that the energy losses are higher in samples having large grains than in samples with small grains (Dou *et al.,* 1993).

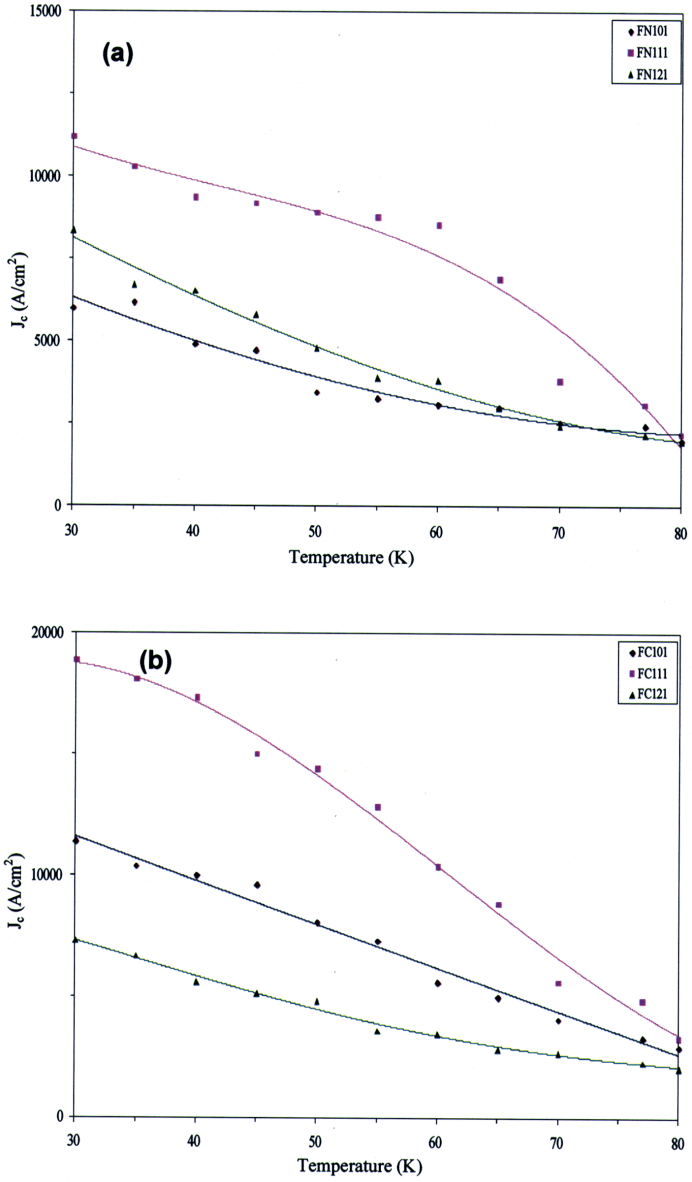
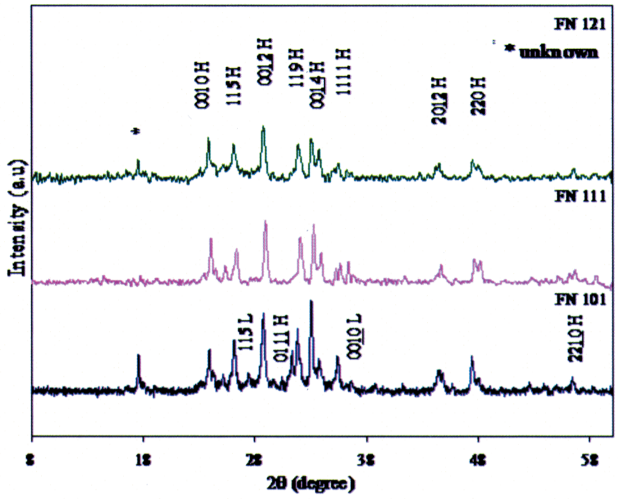
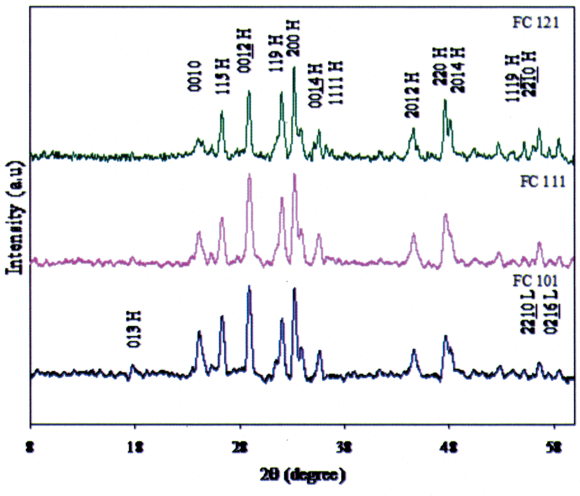


Fig. 1: Critical current density J_c vs. temperature with different temperature dependences for (a) Bi-2223 tape (b) after Co_3O_4 added

Fig. 2 shows the effect of temperature and sintering time duration on XRD spectrum to $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$, and $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$-$(Co_3O_4)_{0.01}$ tape core in Ag sheet. Sintering temperature from 840°C to 845°C reduced 2201 and 2212 phase peaks. 115 L, 0111 L and 0110 L peaks reduced when the sintering temperature increased. Number of peaks in 2223 phase domination shown in *Fig. 2(b)* where 200 H maximum peak in FC 111 sample. *Fig. 2* clearly shows the sample shift from 2212 phase to 2223 phase. This study shows that the addition of Co_3O_4 inhibits 2223 phase formation.



(a)



(b)

Fig. 2: XRD spectrum for (a)$(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$, 840°C (FN101), 845°C (FN111) and 850°C (FN121) (b)$(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$-$(Co_3O_4)_{0.01}$, 840°C (FC101), 845°C (FC111) and 850°C (FC121), sintered for 50 hour

CONCLUSIONS

This study found that the addition of Co_3O_4 increases the pinning strength in Ag-sheathed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ tapes. Magnetic impurities generally suppress conductivity. However, our results show that Co_3O_4 can be employed to enhance the flux pinning capability of Ag-sheathed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ tapes leading to enhancement of J_c in the system. The various sintering temperatures show that the 2223 phase formation increases at higher temperatures. It also happens when Co_3O_4 is added.

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