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EFFECT OF NANO Cr_2O_3 ADDITION ON (Bi-Pb)-Sr-Ca-Cu-O SUPERCONDUCTOR

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ABSTRACT

The effect of nano Cr_2O_3 addition on (Bi,Pb)-Sr-Ca-Cu-O superconductor has been studied. The samples were prepared from the co-precipitation method in the bulk form. Both the critical temperature (T_c) and critical current density (J_c) were determined by the four point-probe technique. Phases analyses of the samples by XRD, microstructures determination by SEM and distribution of nano Cr_2O_3 by EDAX have been carried out. The maximum T_c and J_c were observed for 0.1 wt% nano Cr_2O_3 in the initial sample. The increase in the J_c of all the samples can be explained due to the effective flux pinning of nano Cr_2O_3 to the samples**.**

INTRODUCTION

Multi-phase superconductor system Bi-Sr-Ca-Cu-O was discovered by Maeda *et al*. in 1988 [1]. It was found that a small amount of CrO_3 doping improves the flux pinning, with the effective pinning center due to Cr substitution for Cu, while excessive Cr-ion doping degrades the superconductivity of $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_{10}$ (2223) [2]. T_c of the Cr-doped Bi-Sr-Ca-Cu-O decreased due to the decrease of the hole concentration through substitution of Cr^{3+} for Cu^{2+}. The substitution also causes appreciable change in the normal sate conductivity [3]. At 77 K, self-field J_c of the Nd-added samples are found much better than undoped one [4]. To the best of our knowledge, nano Cr_2O_3 addition on Bi-Sr-Ca-Cu-O superconductors have not been reported earlier. In this paper, we report on the effect of nano Cr_2O_3 addition in Bi-Sr-Ca-Cu-O on the critical temperature (T_c), the critical current density (J_c) at 77 K and the phase variations. The distribution of nano Cr_2O_3 in the samples is also presented.

METHODOLOGY

The samples were prepared from ultrafine superconductor powders developed from the co-precipitation method. Nano Cr_2O_3 (about 100 nm) with the amount of 0.1 wt%, 0.3 wt%, 0.5 wt%, 0.7 wt% and 1.0 wt% were added to the powder. Samples were pressed into pellets of 13 mm diameter and 2 mm thickness and sintered at 850 ºC for 48 hours. The electrical resistance-temperature measurements were carried out by the four point-probe technique in conjunction with a CTI cryogenics closed cycle refrigerator Model 22. The critical current density was measured on bar-shape sample at 77 K. The critical current density was determined using the 1 μV/cm criterion. Powder X-ray diffraction

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measurement was performed using a Siemens D 5000 diffractometer with CuK_{α} radiation. The volume fraction of the 2223 phase and $(Bi_{1.6}Pb_{0.4})Sr_2CaCu_2O_8$ (2212) phase was estimated by assuming that the amounts of those phases are proportional to the strongest diffraction line of each phase. Microstructures were determined from scanning electron micrographs (SEM). The distribution of nano Cr_2O_3 was investigated through the Energy Dispersive X-Ray Analysis (EDAX).

RESULTS AND DISCUSSION

$T_{c\text{-}onset}$, $T_{c\text{-}zero}$, J_c at 77 K, percentage of the 2223 and 2212 phase and distribution of nano Cr_2O_3 are shown in Table 1. Figure 1 shows the electrical resistance versus temperature curve for the samples. The result shows that $T_{c\text{-}onset}$ for the 0.1 wt% nano Cr_2O_3 is the highest, which is 111 K whereas the non-added sample show $T_{c\text{-}onset}$ of 108 K. When nano Cr_2O_3 addition is increased from 0.3 wt% to 1.0 wt%, we found that $T_{c\text{-}onset}$ has decreased from 110 K to 100 K whereas $T_{c\text{-}zero}$ has decreased from 97 K to 81 K.

Table 1: $T_{c\text{-}onset}$, $T_{c\text{-}zero}$, J_c at 77 K, percentage of phase 2223 and 2212 and distribution of nano Cr_2O_3.

x (wt%)	$T_{c\text{-}onset}$ ($\pm$1 K)	$T_{c\text{-}zero}$ ($\pm$1 K)	J_c at 77 K (mA/cm^2)	Volume Fraction (%)		Distribution of Nano Cr_2O_3 (count/μm^2)
				2223 (%)	2212 (%)	
0	108	98	0.03	62	38	-
0.1	111	101	3980	71	29	0.09
0.3	110	97	592	69	31	-
0.5	108	97	393	68	32	0.29
0.7	105	88	14	68	32	-
1.0	100	81	-	67	33	0.57

Further addition of nano Cr_2O_3 up to 1.0 wt% decrease both $T_{c\text{-}onset}$ and $T_{c\text{-}zero}$ of the samples. The decrease of the critical temperature is caused by the over-doping of nano Cr_2O_3 to the Bi2223 system. Barik *et al*. (2000) reported the suppression of T_c with increase of Cr concentration supports the pair-breaking mechanism. Hu *et al*. (2001) has reported that a small amount of CrO_3 doping improves the flux pinning, with the effective pinning center due to Cr substitution for Cu, while excessive Cr-ion doping degrades the superconductivity of Bi2223.

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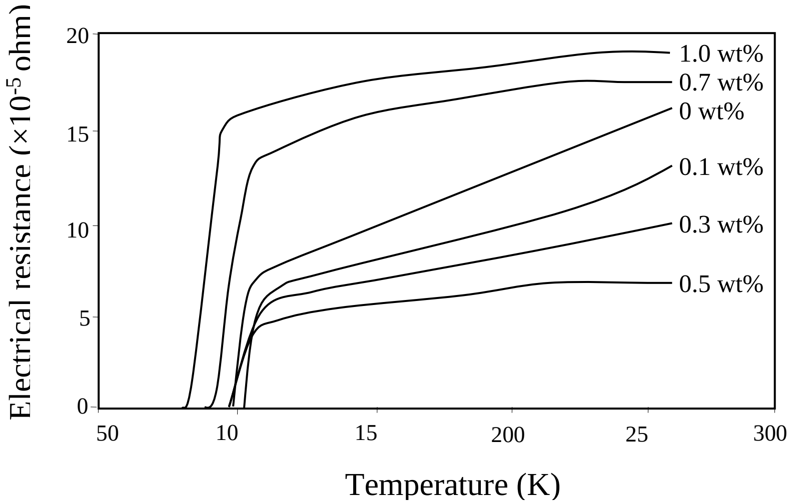

Figure 1: Electrical resistance versus temperature curve.

For the non added sample, the J_c at 77 K is about 0.03 mA/cm^2. J_c of the sample has been increased to 3980 mA/cm^2 while 0.1 wt% nano Cr_2O_3 addition is applied. J_c starts to decrease when the higher amounts of nano Cr_2O_3 are added. There is an increase in J_c for the all the nano Cr_2O_3-added samples compared to the non-added sample. In other words, the flux pinning strength of the added samples is significantly enhanced compared to the non-added sample. Meanwhile, the presence of nano Cr_2O_3 in the Bi2223 samples, has acted as an effective flux pinning centres.

Figure 2 shows the XRD patterns of the samples. The main peaks can be identified as (020). These samples do not show single phase because it has been found that there are a few peaks which show the phase of 2212.Volume fraction can be calculated from the X-ray intensity of the (020) peaks of Bi2223 and the (*) peaks of Bi2212. The volume fraction of 2223 phase for sample with the addition of 0.1 wt% nano Cr_2O_3 shows the highest percentage, which is 71%. However, there is not much difference in the volume fraction when further addition of nano Cr_2O_3 is applied. The results show that a small amount of nano Cr_2O_3 has no influence on the Bi2223 system. From the result, it shows that the highest percentage of 2223 phase may give the highest critical temperature.

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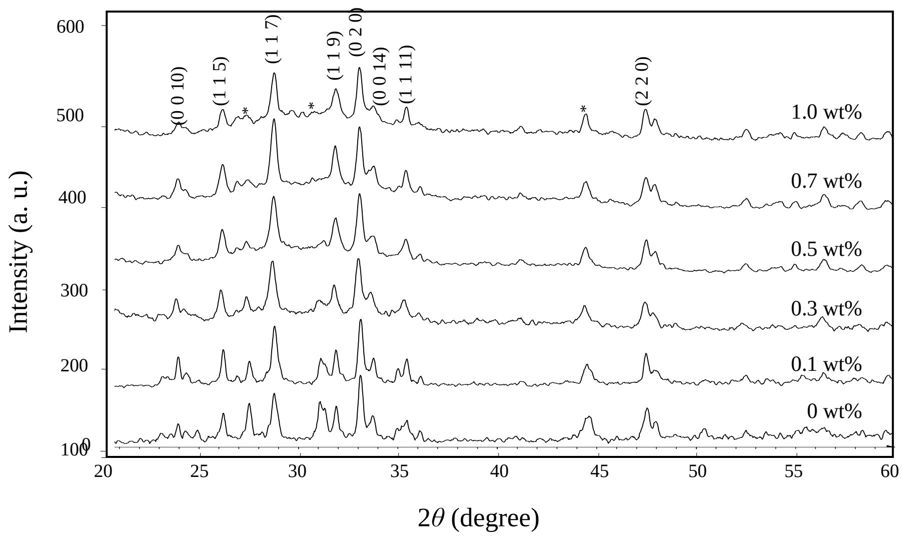
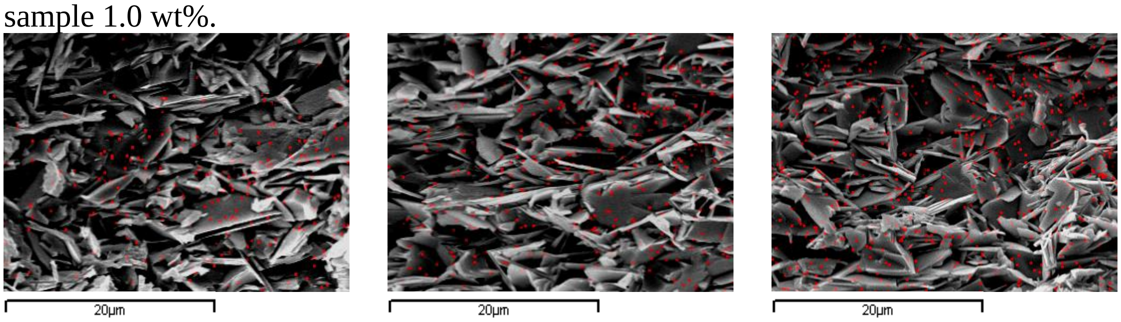


Figure 2: XRD patterns of the non-added and nano Cr_2O_3-added samples; (*) denotes the Bi2212 phase.

Figure 3 shows the SEM micrograph for samples with addition of 0.1 wt%, 0.5 wt% and 1.0 wt% nano Cr_2O_3. All of the samples show the similar grain alignment. Meanwhile, the adding amount is very small and does not change the grain size and alignment. The distribution of Cr_2O_3 is showed by the red spots. The distribution of nano Cr_2O_3 increases from 0.09 count/μm^2 for sample 0.1 wt%, to 0.57 count/μm^2 for sample 1.0 wt%.



(a) (b) (c)

Figure 3: SEM micrographs of samples (a) 0.1 wt%, (b) 0.5 wt% and (c) 1.0 wt%.

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CONCLUSION

Nano Cr_2O_3 additions on Bi-Sr-Ca-Cu-O can improve the superconducting properties of the samples. Sample with the addition of 0.1 wt% has the highest $T_{c\text{-}onset}$ and $T_{c\text{-}zero}$. The same sample also shows the highest volume fraction of 2223 phase which is 71%. The results show that an appropriate amount of nano Cr_2O_3 can improve the superconducting properties of the Bi-based samples, while excessive nano Cr_2O_3 addition leads to the degradation of superconductivity of Bi2223. J_c of all the samples has been increased with addition of nano Cr_2O_3. Nano Cr_2O_3 addition in very small percentage in (Bi, Pb)-2223 will enhance the critical current density effectively.

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