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DYNAMIC MAGNETIC PROPERTIES OF Mn DOPED $YBa_2Cu_3O_{7-\delta}$ SUPERCONDUCTING CERAMICS

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ABSTRACT

AC complex susceptibility, $\chi = \chi' + i\chi''$, *measurements were done on the* $YBa_2Cu_3O_{7-\delta}$ *superconducting samples doped with Mn at Y, Ba and Cu sites Y123 with nominal starting composition (x = 0.02 and 0.1). The data of* χ' *shows that the coupling of the grains in samples that doped at Cu site are weaker than that samples doped at Y and Ba sites as shown by using the Ambegaokar-Baratoff equation* $I_0 = 1.57 \times 10^{-8} T_c^2/(T_c - T_{cj})$, *the calculated values of Josephson current,* I_0 *where* $I_{0(in\ Y)} > I_{0(in\ Ba)} > I_{0(in\ Cu)}$ *due to the weakening of the grain's coupling. This observation is supported by the intrinsic coupling loss,* T_P *obtained from* χ'' *that shows a bigger shift of the intergranular coupling peak,* T_P, *towards lower temperature in Mn doping at Cu site as compared to the doping in Ba and Y sites. Hence the effect of doping is obvious at higher concentration for all samples. Analysis based on the sensitivity of the data of* $d\chi'/dT$ *versus temperature furnished further information on the two step transition related to the coupling of the grains in all systems.*

Keywords: Mn doping, High temperature superconductor, $YBa_2Cu_3O_{7-\delta}$

INTRODUCTION

AC susceptibility technique is now commonly used in the characterization of superconducting materials. The discovery of superconductivity at temperatures around 92 K in $YBa_2Cu_3O_{7-\delta}$ opened up new horizons in the field of high temperature superconductors. The discovery of the "123" material has sparked a flurry of activity as researchers sought other high temperature superconductors (HTSC) and has led to the discovery of the bismuth [1], thallium [2], and mercury [3] systems of high temperature superconductor.

Little attention has been given to the Mn substitution, which is a 3d transition metals as well as other metals from the same series because of their small solubility in the structure. It is reported from neutron diffraction and EXAFS work that Mn prefers the Cu(1) sites since there are two non-equivalent Cu sites Cu(1) and Cu(2) in the crystal structure of $YBa_2Cu_3O_{7-\delta}$ [4-6]. ESR and Raman spectra [7] show that the content of Mn ions in the CuO2 plane is saturated when x is increased above0.05 in $YBa_2Cu_{3-x}Mn_x O_{7-\delta}$. However, Jardim et al.[8-9] found that the substitution of Cu by Mn preserves the orthorhombic structure and leads to a minute diminution of the T_C up to x = 0.3, and that the solubility limit of Mn in (123) structure is near 0.075. The amounts of extra phases, Y_2BaCuO_5 and the tetragonal $Ba_2Mn_3O_8$ increases with the increase of x [9]. Some of the questions regarding to normal state properties still remain unanswered.

In this paper we study the effects of Mn doping at Y, Ba and Cu sites in $YBa_2Cu_3O_{7-\delta}$ system with nominal composition (x = 0.00, 0.02, and 0.10). The superconducting and magnetic properties of Y123 phase will be discussed.

EXPERIMENTAL PROCEDURE

Powders of $YBa_2Cu_3O_{7-\delta}$ were obtained by mixing Y_2O_3, $BaCO_3$, CuO and MnO (purity ≥ 99.99 %) in appropriate proportions. The mixed materials were ground in a mortar and calcined in air at 920 ^{0}C for 48 hours with several intermittent grindings followed by oven cooling at 60 ^{0}C per hour. The powders were reground and then pressed into pellets of ~10 mm diameter and 3 mm thickness. The pellets were sintered at 920 °C for 24 hours and slow cooled to room temperature at 60 °C per hour.

The samples were examined by X-ray powder diffraction with Cu_{α} radiation using Phillips W1830 diffractometer. Scanning electron microscope (SEM) micrographs were recorded using a JEOL 6400 unit. AC susceptibility measurements were also carried out using Lakeshore AC susceptometer model 7000. The amplitudes of the ac fields were varied between 0.1 Oe to 10 Oe at a fixed frequency of 125 Hz.

RESULTS AND DISCUSSION

The temperature variation of the complex magnetic susceptibility, $\chi = \chi' + i\chi''$, in various ac fields H, for all samples are shown in Figs. 1-3. The applied field was varied between 0.1 to 10 Oe at constant frequency of 125 Hz. The curves of real part (χ') provide information on the diamagnetic behavior while the imaginary part (χ'') displays the features of coupling effect of the grains in the superconductor. However, the peaks associated with the intragranular loss near T_C were not observed. The graphs show the shifting toward the low T_C as Mn concentration increased. The data of χ' shows that the coupling of the grains in samples doped at Cu site are weaker than samples doped at Y or Ba sites.

The Josephson's current I_0 passing through the grains boundaries for all the samples has been calculated by determining the phase locking temperature, T_{cj} associated with the onset of the lower transition temperature and using the Ambegaokar-Baratoff [10] equation, $I_0 = 1.57 \times 10^{-8} T_c^2/(T_c - T_{cj})$, are summarized in Table 1. I_0 decreases as Mn substitution increase in all sites due to the weakening of the grain's coupling. In addition the the decreasing in I_0 value found to be very big in samples doped at Cu site as compared to samples doped in Ba site and Y site which is due to the weakening of the grain's coupling. The Josephson coupling energy between the grains, as calculated by using $Ej = (h/4\pi e)I_0$ [11], where I_0 is the maximum supercurrent through the junction, h is the Planck constant and e the electron charge, are also included in Table 1.

Table 1 Calculated values of maximum Josephson current (I_o) and coupling energy (Ej) for YBCO at different doping ratios.

Mn concentration		T_C	T_{Cj}	I_o(μA)	Ej(x 10^{-20})
Pure	x = 0	93.77	91.89	70.5145	2.3243
Doping in Y site	x = 0.02	93.1	89	33.1906	1.0940
	x = 0.1	92.72	86.88	23.1118	0.7618
Doping in Ba site	x = 0.02	92.03	87.24	27.7602	0.9150
	x = 0.1	88.9	81.3	16.3264	0.5381
Doping in Cu site	x = 0.02	93	87.48	24.5995	0.8108
	x = 0.1	88.07	79.4	14.0455	0.4630

This observation is supported by the intrinsic coupling loss, T_P obtained from χ'' that showed a bigger shift of the intergranular coupling peak, T_P, towards lower temperature in Mn doping at Cu site as compared to the doping in Ba and Y sites, respectively. Hence the effect of doping is obvious at higher concentration for all samples this result is confirmed the magnetic filed versus T_P values for the doped samples. However, the value of T_P tends to decrease with the increase of applied fields as shown in Fig. 4 and Fig. 5.

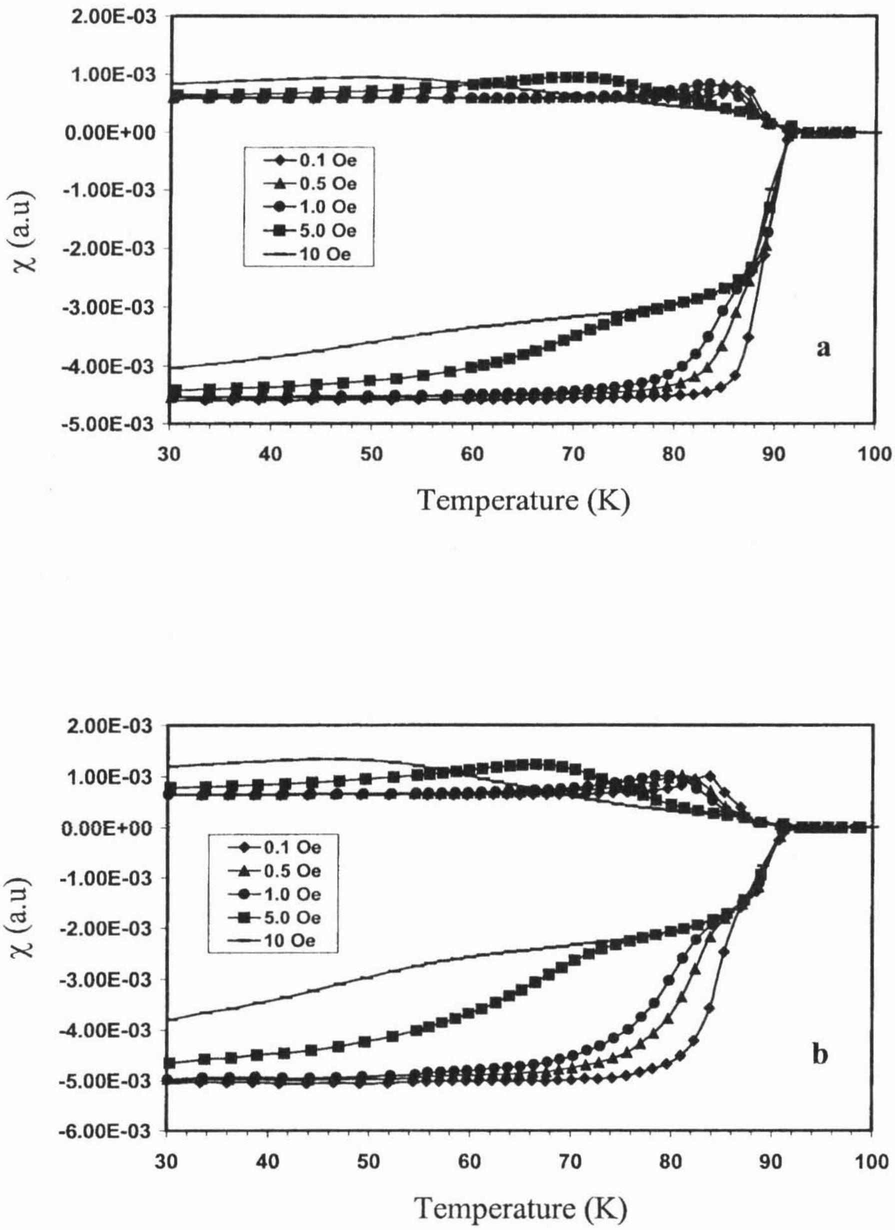


Fig.1 AC susceptibility vs. temperature for $YBa_2Cu_3O_{7-\delta}$.doped with Mn at Y site (a) x= 0.02 and (b) x= 0.1.

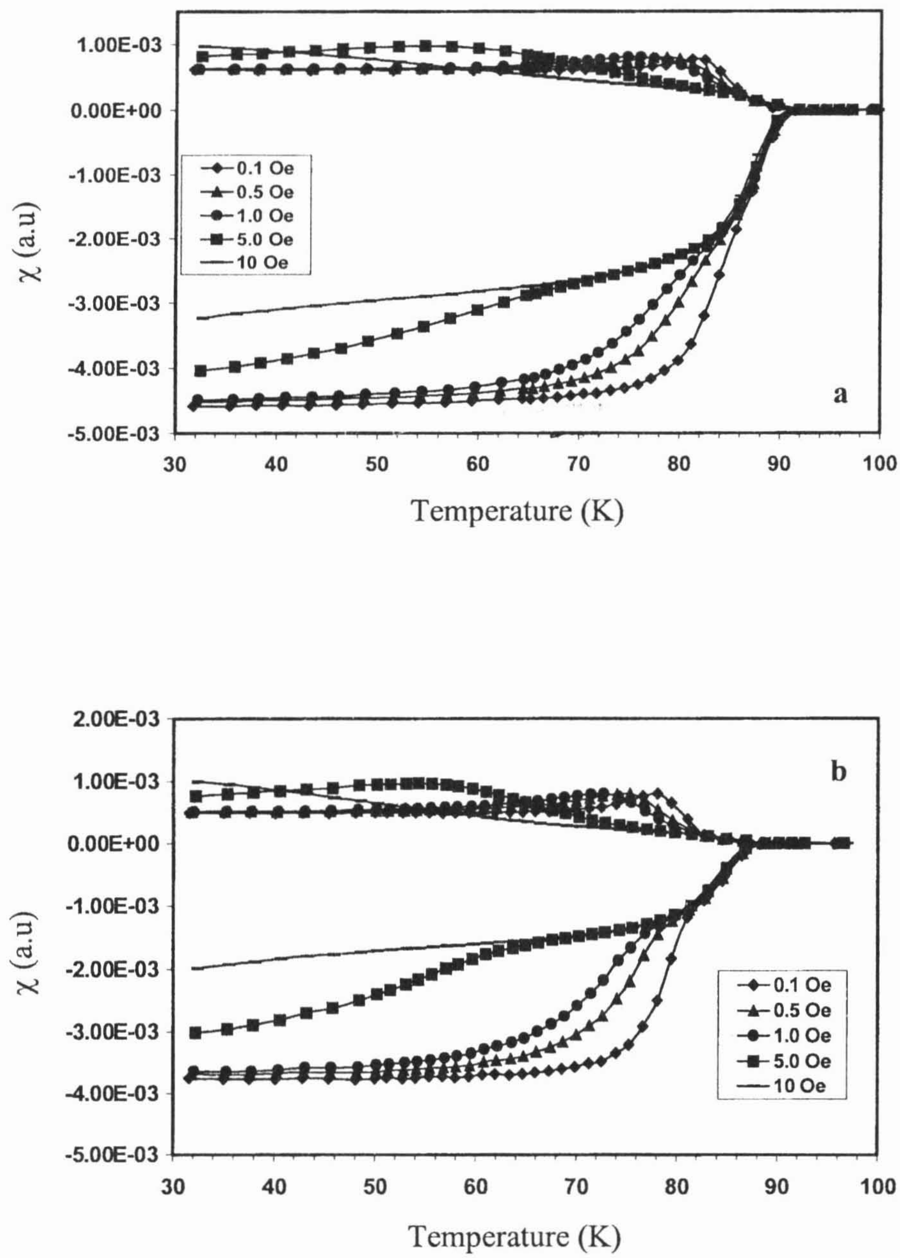
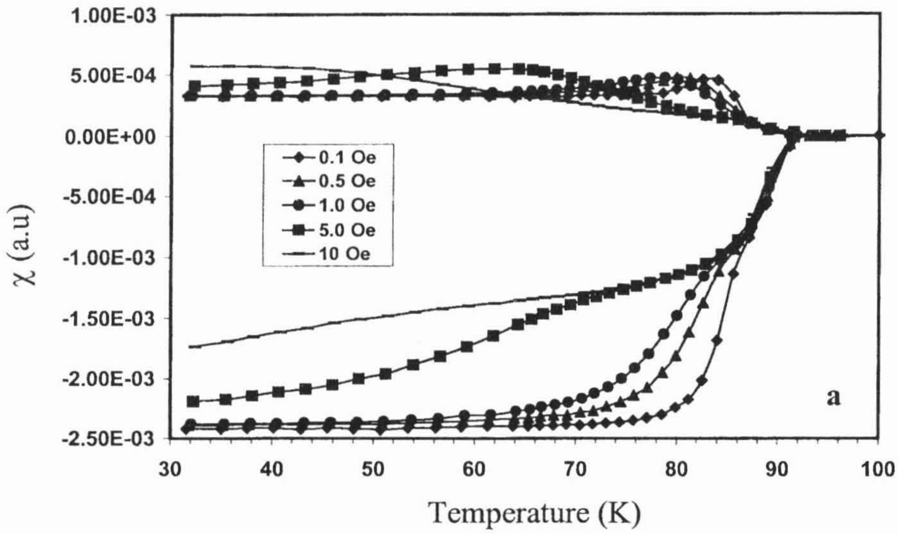


Fig. 2 AC susceptibility vs. temperature for $YBa_2Cu_3O_{7-\delta}$.doped with Mn at Ba site (a) x = 0.02 and (b) x = 0.10.



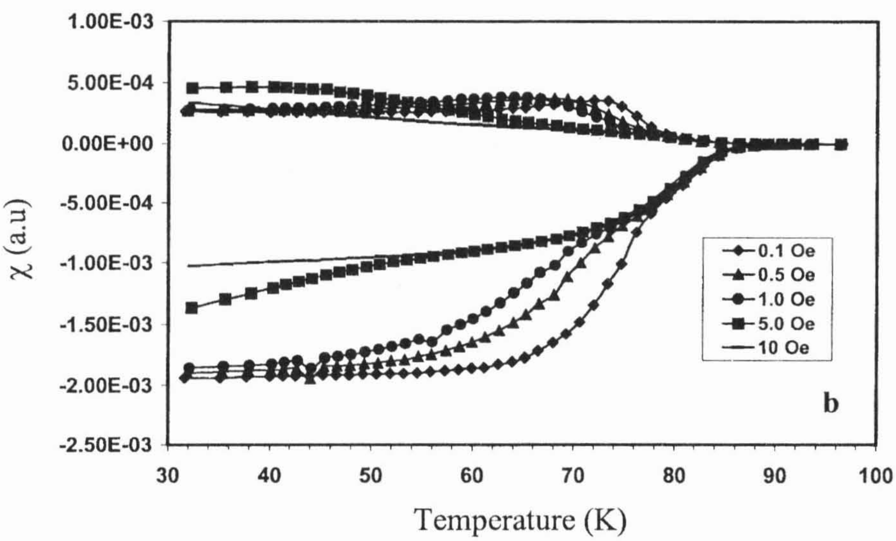


Fig. 3 AC susceptibility vs. temperature for $YBa_2Cu_3O_{7-\delta}$.doped with Mn at Cu site (a) x = 0.02 and (b) x = 0.10.

Analysis based on the sensitivity of the data of $d\chi'/dT$ versus temperature furnished further information on the two step transition related to the coupling of the grains in all systems as shown in Fig. 6. The peaks observed, which correspond to the mid-point of the transition, in the high temperature transition for the samples that doped at various sites with nominal concentration $x = 0.02$ as displayed in Fig. 6(a). For sample doped at Y site shows single, sharp peak at 89 K which is due to the good connectivity between the grains as compared to the same concentration for the samples doped at Ba and Cu sites where the existence of two peaks are obvious with a temperature difference of about 5 K. All samples doped at nominal concentration of 0.1 and at different sites are found to consist of two separated peaks as shown in Fig.6 b. The separation of the first peaks between samples doped at Y site and the sample doped at Ba site is 4 K and between the later sample and the sample doped at Cu site is 4 K towards low temperature. However, the separations of the two peaks in the later doped samples are 5 K, 6.4 and 6.1 K, respectively.

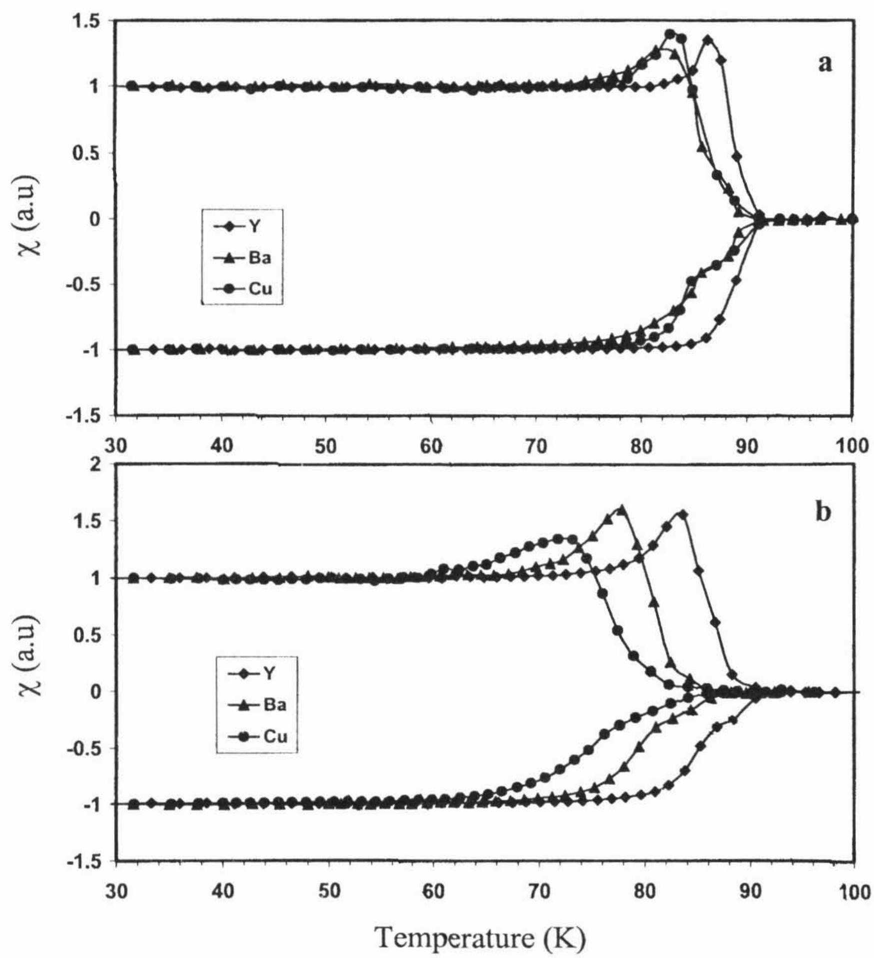


Fig. 4. AC susceptibility vs. temperature for $YBa_2Cu_3O_{7-\delta}$ .doped with Mn at different sites (a) $x = 0$, 0.02 and (b) $x = 0.1$ at applied field, H = 0.1 Oe.

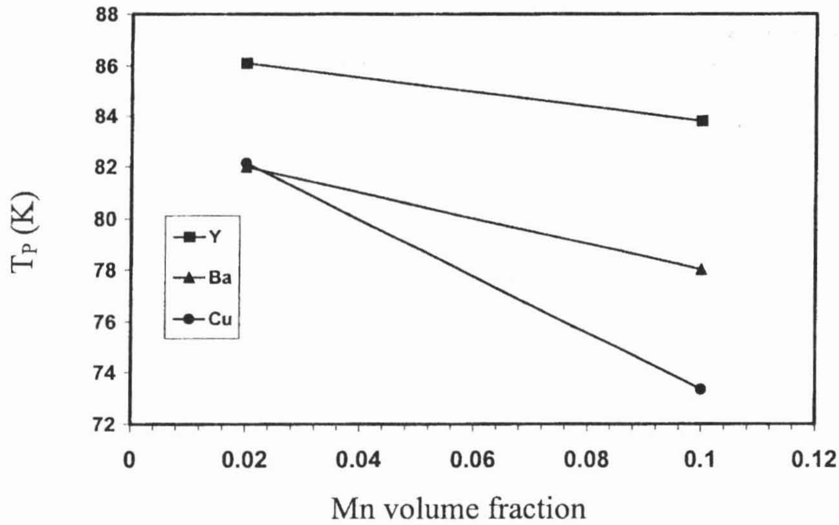


Fig. 5 Magnetic filed versus T_p values for $YBa_2Cu_3O_{7-\delta}$ at different sites (x = 0, 0.02 and 0.1)

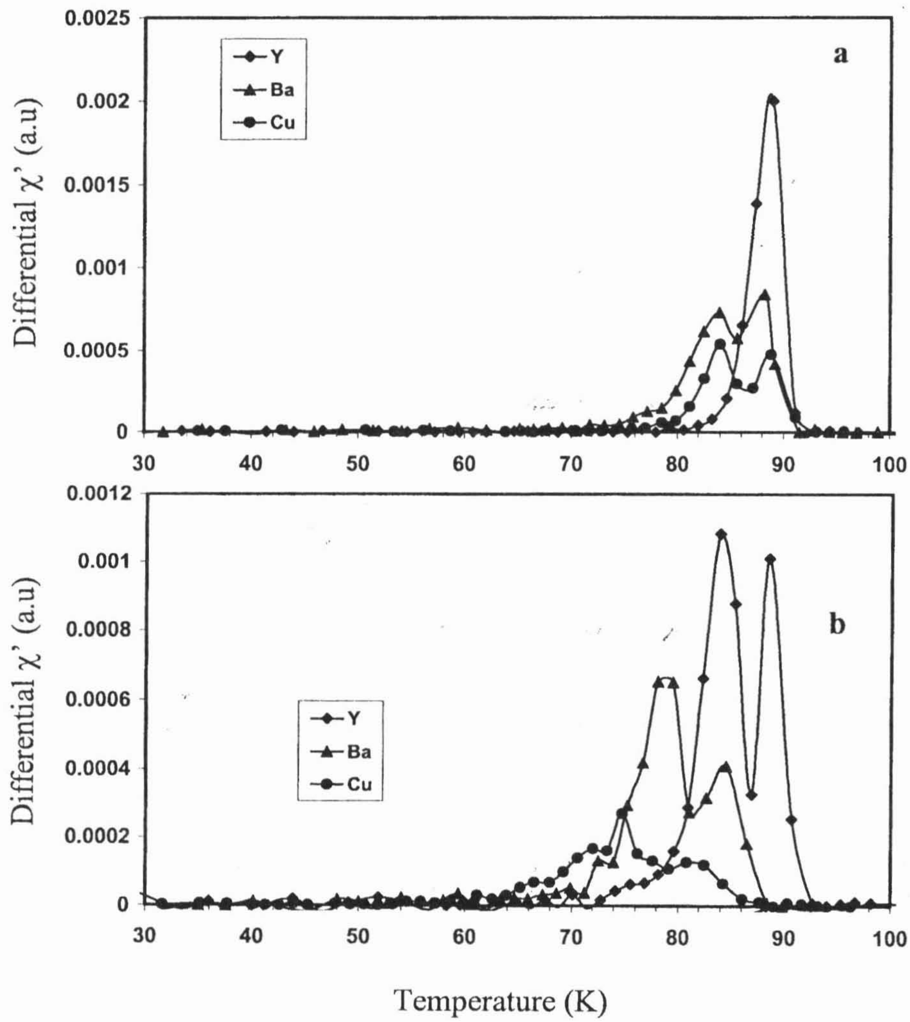


Fig. 6 χ'/dT versus temperature for doped samples at nominal composition (a) 0.02, (b) 0.1.

CONCLUSION

Mn substituted Y123 type phase high temperature superconductors with nominal starting composition $YBa_2Cu_3O_{7-\delta}$ (x = 0, 0.02 and 0.1) at all sites have been prepared and characterized by ac susceptibility. It showed that the coupling of the grains in samples doped at Cu sites are weaker than that samples doped at Y and Ba sites. The calculated values of Josephson current, I_0 where $I_{0(in\ Y)} > I_{0(in\ Ba)} > I_{0(in\ Cu)}$ due to the weakening of the grain's coupling. The intrinsic coupling loss, T_P showed a bigger shift of the intergranular coupling peak, T_P, towards lower temperature in Mn doping at Cu site as compared to the doping in Ba and Y sites. Hence the effect of doping was obvious at higher concentration for all samples.

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