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INFLUENCE OF DIFFERENT SOLID STATE ROUTES ON SUPERCONDUCTING OF $Tl_2Ba_2CaCu_2O_8$ SUPERCONDUCTORS ADDING WITH NANO Ag

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ABSTRACT

The thallium-based cuprate superconductors $Tl_2Ba_2CaCu_2O_{8,}$ (Tl 2212) with nano Ag addition have been synthesized via the solid state reaction method. The $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$ have been prepared using two different methods A and B. In method A, nano Ag was added into prereacted Tl2212 powders. In method B, nano Ag was added into unreacted $Tl_2Ba_2CaCu_2O_8$. The four point probe method, X-ray powder diffraction and scanning electron microscopy (SEM) have been employed to study the materials. Resistance data for both method showed little effect on $T_{c\ onset}$ and T_{czero} . $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$ using both methods A and B with x = 0-5 wt% showed $T_{c\ onset}$ of 112-107 K and $T_{c\ zero}$ of 100-96 K. The effect of using various methods on critical current densities was studied. By using method A, it was found that the sample with x = 1 wt% showed maximum critical current density, J_c (at 77 K) of 16.47 mA/cm^2. Therefore, by using method B, sample with x = 3 wt% showed the maximum critical current density, J_c (at 77 K) of 1505 mA/cm^2. Thus, it can be concluded that the different methods of preparation influence the superconducting properties of the samples. The possible reasons for the changes in superconductivity properties of the system studied will be discuss in this paper.

INTRODUCTION

Since the discovery of Tl-Ca-Ba-Cu-O superconductor with T_c values obtained above 100K, there has been a great effort to prepare single-phase superconducting compounds. However, for the preparation of single –phase superconducting compound, which is necessary to obtain high values for the critical current in the bulk samples still remained a major problem. Low values of J_c are the primary reason that the superconductor material not yet found for the practical applications.

It is well known that the critical current density, J_c is the most significant parameter for superconducting applications. To enhance J_c of bulk superconductors, various methods and techniques have been employed to overcome the factors that limit the J_c value. One of them is by adding small amount of additive particle such as Ag [1,2] ,

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nano Cu [3] and nano SnO_2 [4]. Recently, several groups have investigated the influence of nano particle addition on superconductivity properties of superconductor material. The addition of nano particle with appropriate amount have been reported improved the J_c value, especially at low magnetic field by enhancing the flux-pinning properties of the high-temperature superconductor and phase formation [4].

In the literature, some authors have reported that Ag doping enhances the critical current density in the Bi-(Pb)- Sr-Ca-Cu-O system and some others have reported conflicting results [5]. Consequently, it is desirable to provide additional observations which contribute in resolving this controversy or the shed light on the origin of the conflicting results.

The purpose of this study is to understand the effects of silver addition by using two different route of sample preparation on the superconductivity properties of $Tl_2Ba_2CaCu_2O_8$. Powder X-ray diffraction, d.c. electrical resistance-temperature measurement and scanning electron microscopy are used to investigate the superconducting phase, superconductivity and microstructure respectively.

EXPERIMENTAL DETAILS

The $Tl_2Ba_2CaCu_2O_8.(Ag)_x$ have been prepared using two different methods A and B. In method A, nano Ag was added into prereacted Tl2212 powders. In method B, nano Ag was added into unreacted $Tl_2Ba_2CaCu_2O_8$. The samples were prepared using solid state method. Polycrystalline samples Tl2212 superconductor were prepared using high purity CaO, BaO, CuO powders ($\geq$ 99.99%). The powder were weighed and mixed thoroughly to obtained required stoichiometic ratios. The powder were then calcined in air at 900^{o}C for 48 hours with one intermittent grinding . Approriate amounts of Tl_2O_3 were then added to the $Ba_2CaCu_2O_5$ precursor powder with nominal starting composition $Tl_2Ba_2CaCu_2O_8$. The unreacted powder was then ground for 1 hours. The powder were then pressed into pellets of 13 mm diameter and 2 mm thickness under a load of 6 metric tons using hydraulic press. The pellet was sintered at 900^{o}C for pure samples in oxygen flow for 4-5 mins followed by furnace cooling. The reacted $Tl_2Ba_2CaCu_2O_8$ were then ground and mixed with with nano Ag particle with amount 1wt%, 3wt%, and 5wt% respectively. The pellet was sintered at the same condition as mentioned above for second time. In the case for sample added with 1-5wt% concentration of nano Ag the sintering temperature is 880^{o}C. This value of temperature was chosen due to the samples melt when sintered at temperature above 880^{o}C.

For samples preparation using method B, the unreacted $Tl_2Ba_2CaCu_2O_8$ powder was then ground for 1 hours and mixed with nano Ag particle with amount 1wt%, 3wt% and 5wt. Resistivity measurements of the samples were carried out using the four point probe d.c. method with silver paste contacts. The experimental set up consisted of a closed cycle refrigerator from CTI Cryogenics (model 22) a temperature controller

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from lake shore (model 330). The critical current density (J_c) was measured on bar shaped samples. The critical current densities were determined using the 1 μV/cm criterion. The transport critical current density J_c was calculated by dividing the citical current, I_c of the bar shape with the corresponding cross sectional area. A philips XL-30 scanning elecrtron microscope was used to observe the microstructure of the bulk samples. A Bruker D8 Advance diffractometer with CuKα radiation was used to determine the X-ray diffraction pattern.

RESULTS AND DISCUSSION

We label A0 (non added sample), A1 and A3 for sample having 1 and 3 wt% of nano Ag powder respectively. Simirlaly, B1 and B3 for samples that prepared by using method B with 1 and 3 wt % level concentration of nano Ag.

Phase formation

Figure 1 shows the XRD patterns of samples A0, A1 and B3. From Figure 1, we can see that the diffraction pattern of the samples consisting of Tl-2212 phase, Tl-2201, Tl-2223 and impurity phase with different fraction. Peak representing reflection of nano Ag could not be clearly identified in the samples probably due to the low Ag concentration. It was found that when the addition nano Ag is at the level of 1wt% an 3 wt% (A and B method) the Tl-2212 phase became dominant. Compared to non-added samples, the Tl-2212 formation in sample B3 are the highest, almost 100%. The volume fraction of Tl-2212 is found to decrease with increasing of nano Ag concentration, indicating that an excessive addition of nano Ag (for x >3 wt%) affected the formation of Tl-2212 phase and produced large amount of others impurity phase (not shown in the figure 1). The figure shown that different route of sample preparation with the same addition of level of concentration of nano Ag cause different effect to the phase formation of Tl2212 (Refer to table 1).

Table 1: $T_{c\ onset}$, $T_{c\ zero}$, relative volume fractions of Tl 2212, Tl 2223 and Tl 2201 phase, J_c (77 K) for $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$.

Method	Sample	x (wt %)	$T_{c\ onset}$, (K)	$T_{c\ zero}$ (K)	J_c (77K) (A cm^{-2})	Phase (%)		
						2212	2223	2201
	A0	0	112	100	0.18	32	38	30
A	A1	1	113	100	0.02	60	40	0
	A3	3	107	95	-	37	25	37
B	B1	1	108	90	0.05	55	20	25
	B3	3	111	96	1.505	80	20	0

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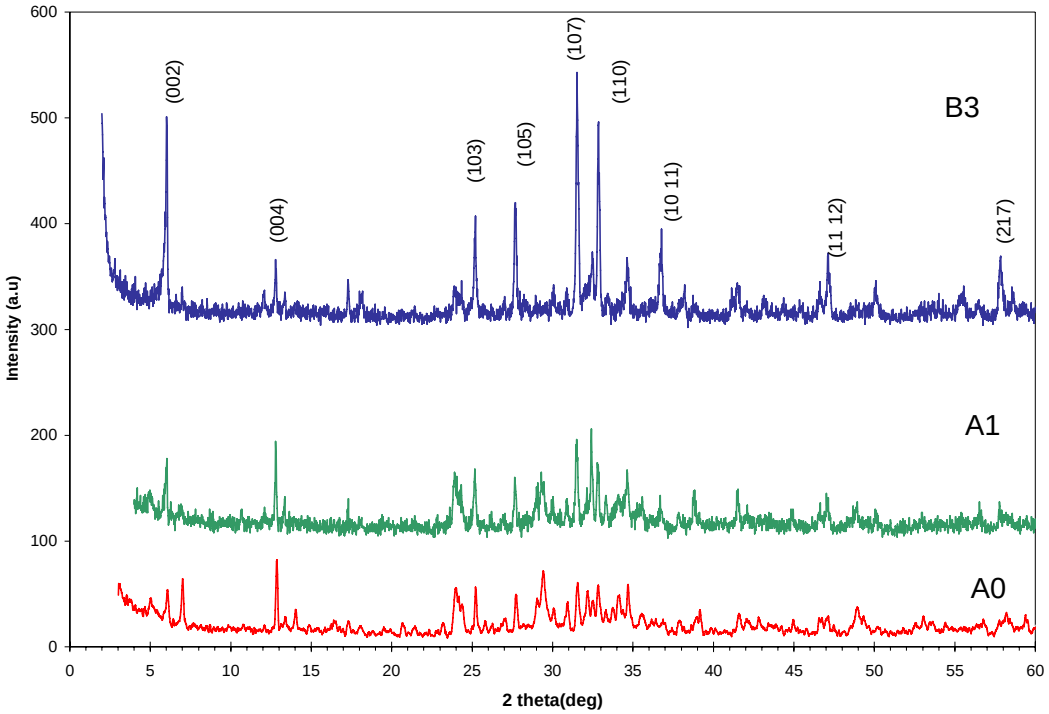
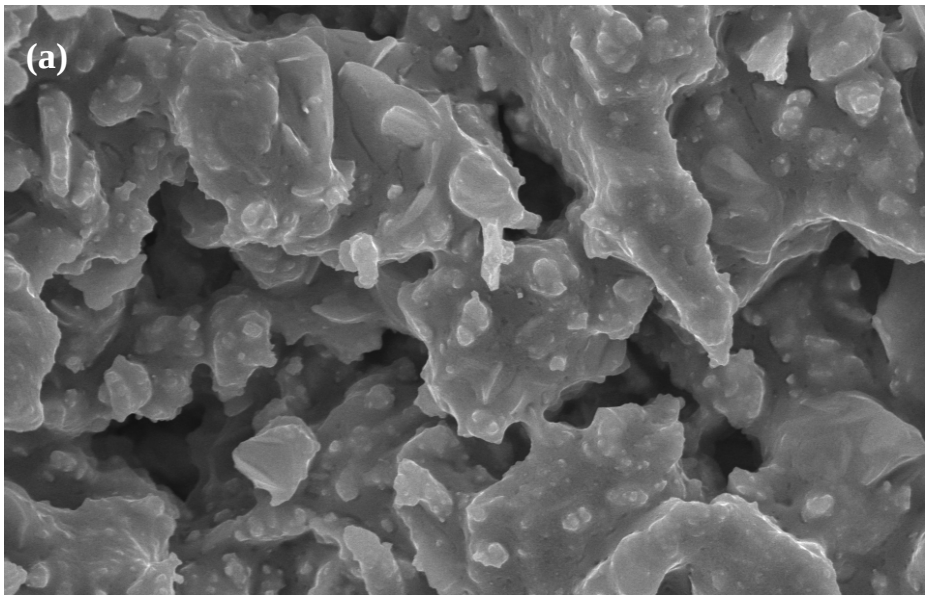


Figure 1: X-ray diffraction pattern of the A0 , A1 and B3 samples.

SEM observation



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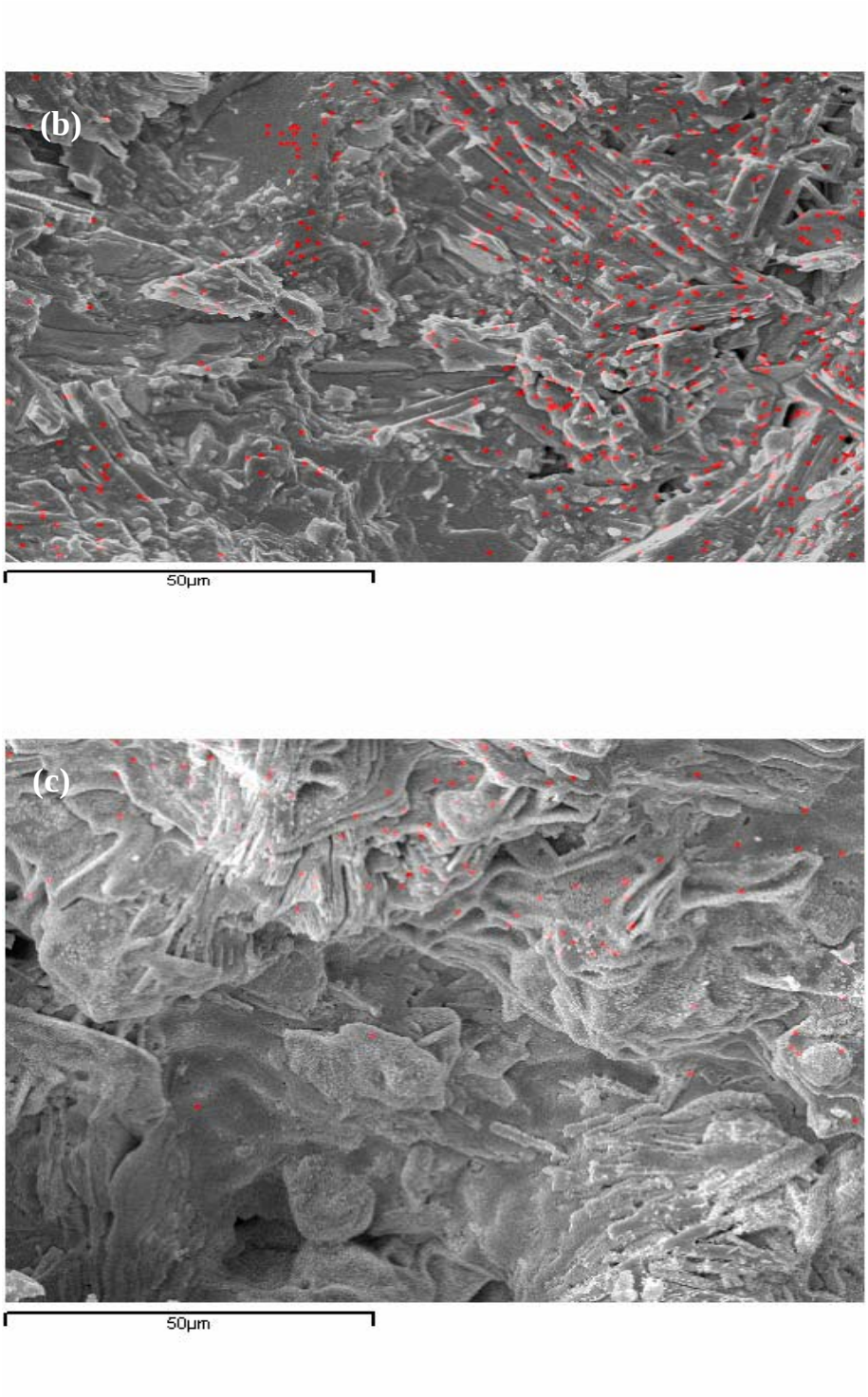

Figure 2 : Scanning electron micrograph for (a) A0, (b) A1 and (c) B3.

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As shown in figure 2, for $Tl_2Ba_2CaCu_2O_{8-}$ Ag_x, it can be clearly seen that sample A1 and B3 , the grains are in close contact with each others compared to sample with A0. Thus, the addition of nano Ag at low content, enhances the connection between superconducting grains which is the most important factor that can increase the J_c. It is found that further addition of nano Ag using both method had consequently changed the morphology of the grains. Not shown in this paper.

Superconductivity and transport critical current densities
The temperature dependence of the electrical resistivity for samples A0, A1 and B3 of $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$ are shown in figure 3. The graph shows that all the samples have a metalic-like behaviour in the normal state. The variation of T_c, determined from the electrical resistivity data, with concentration level of x=1-3wt% for $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$ for both method are shown in Table 1. The data shows that by using both method not give much difference on T_c (onset) and T_c (zero) for x = 1 -3 wt% addition of nano Ag. This indicates that addition of nano Ag with a light doping are not much affects superconducting properties of the material.

Figure 4 shows the critical current density (J_c) versus temperature curve for $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$. The transport critical current densities, J_c decreases with temperature as the consequence of thermal activated flux creep [6]. The effect of nano particle on the critical current density J_c, at 77 K for $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$ with x = 0 –3 wt% are shown in Table 1. It can be seen that J_c decreased with x = 1 wt% by using method A and B. A further addition of nano Ag give rise of J_c with maximum J_c of 1505 mA/cm^2 at 77 K has been obtained for sample added with 3 wt% of nano Ag by using method B.

The 2212 content increases with increase of nano Ag concentration. This result shows that the presence of higher percentage of the 2212 phase contributed to better J_c. (sample B3). In HSTc, transport properties are mainly controlled by the grain boundary microstructure unlike T_c which is determined by the crystal structure and oxygen content. Depending on crystallography and structure of boundary, they can be favourable for the passage of supercurrent or can be weak links (reduced I_c regions) in the superconducting current path of a ceramic sample.

Thus, the decrease in J_c for sampel A1 and B1 and can have two different explanations: it is suggested due to the presence of impurity such as 2223, 2201 and other unidentified compositions that suppress the current carrying capability of this samples, whereas the second is the presence of nano Ag it self with such amount cannot act as effective flux pinning centres even though both of these samples show the highest formation of Tl 2212 phase compared to non-added sample. This result shows that an appropriate amount of nano Ag followed by suitable method can improve the phase formation of Tl2212 and enhances the J_c , which is desirable for further application.

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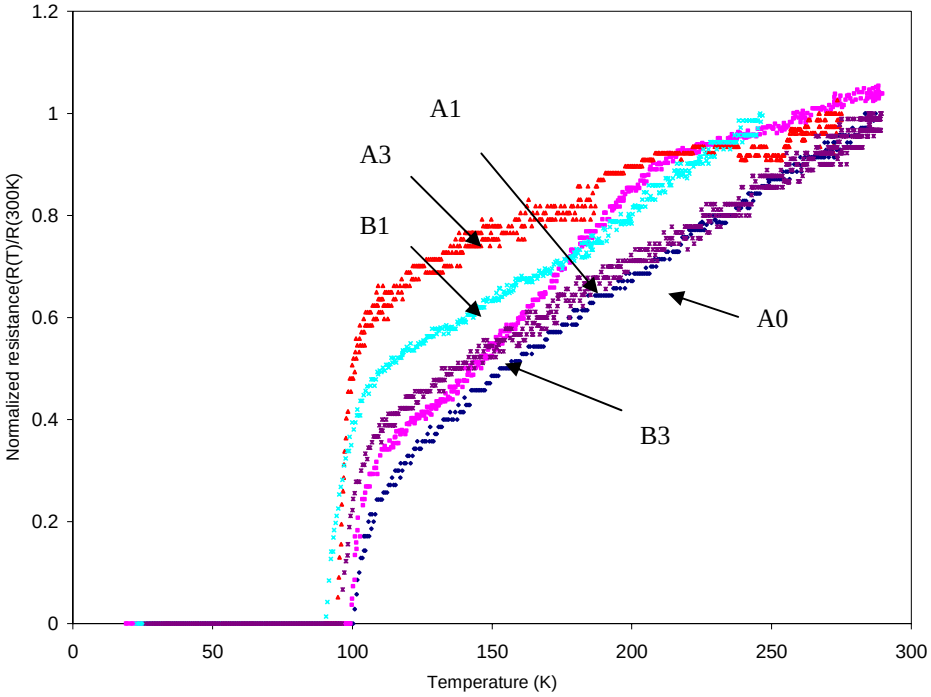

Figure 3: The variation of resistivity with temperature for $Tl_2Ba_2CaCu_2O_8$-$(Ag_3)_x$ with x = 0 and 1 wt% and 3 wt%.

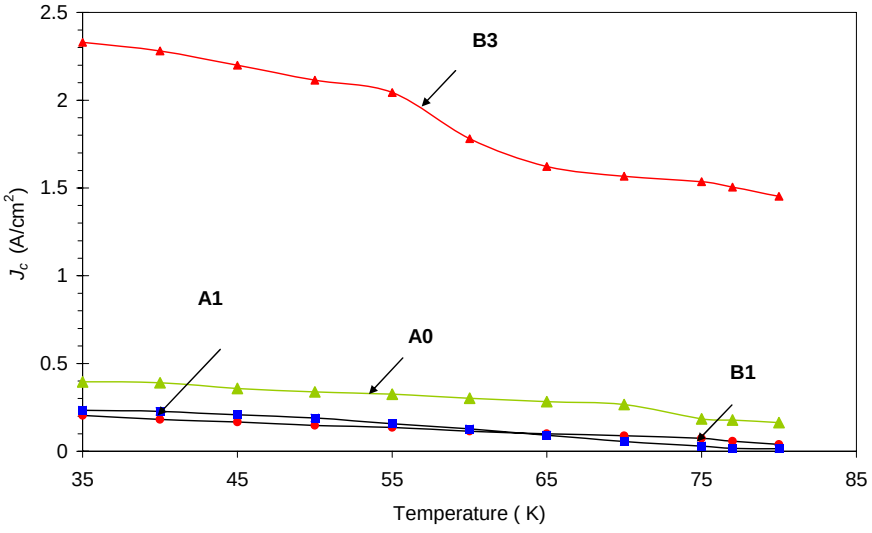

Figure 4: Temperature dependence of J_c in $Tl_2Ba_2CaCu_2O_8$-$(Ag)_x$ for x 0-3wt%.

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CONCLUSION

In this work, nano Ag were introduced into Tl-2212 superconductors. It was found that the transition temperature is decrease as the nano Ag content is increased. Tl- 2212 phase formation is affected by the addition of nano Ag by using different solid states route. A small addition of nano Ag enhances the critical current densities due to improvement of intergrain coupling and enhancing phase formation of Tl2212. We believe that addition of nano Ag enhance J_c of the Tl-2212 samples if prepared under the optimum condition. This study shows that the synthesis method are the important role that must be considered in improving the performance of Tl2212 superconductor. This result is useful for further study in critical current density of HTSc tapes and thin films.

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