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EFFECTS OF NANO CaO IN $Tl(Sr_{1.5}Yb_{0.5})Ca_yCu_2O_{7-\delta}$ SUPERCONDUCTOR

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ABSTRACT

Yb substituted Tl-1212 type phase with nominal starting composition $Tl(Sr_{1.5}Yb_{0.5})Ca_yCu_2O_{7-\delta}$ (y = 1.0, 1.2, 1.3 and 1.4) have been prepared and characterized. The X-ray diffraction patterns indicate that the variation of nanosized calcium oxide for y = 1.0 to 1.4 showed a dominant 1212 phase and the 1201 as the minor phase. This system showed a metallic normal state behavior for all samples. Scanning electron micrographs of fractured internal sections of all the samples showed porous microstructure with grains of similar shapes and sizes.

INTRODUCTION

The $TlSr_2CaCu_2O_7$ (Tl-1212) phase with an average Cu valence of 2.2+ to 2.3+ exhibits the optimum superconducting behavior similar to $YBa_2Cu_3O_7$ (Y-123) [1]. Substitution of rare earth elements of higher valence in the $TlSr_2CaCu_2O_7$ phase may reduce the formal valence of Cu to an optimum value. Such substitution can also stabilize the 1212 phase and improve its superconducting characteristics [2-5].

Substitution of Nd for Sr in the Tl-1212 phase with nominal composition of $Tl(Sr_{0.65}Nd_{0.35})CaCu_2O_7$ results in a superconductor with transition temperature 81 K [6]. Its structure resembles a three-layer perovskite with Ca^{2+} at the cell center and Sr^{2+} at the centers of the outer layers where Cu-O_2 sheets lie above and below the Ca^{2+} ions.

Furthermore, substitution of Yb at Sr site enhanced the formation of the 1212 phase, but the gradual decrease of T_c with Yb was suggested to be due to carrier overdoping as a result of possible increase in oxygen content with increasing Yb which overcompensated the Yb-substitution effect [7].

Nanomaterial addition in superconductor systems is proven to enhance the critical current density, J_c by pinning flux. The addition of small amount of nanosize MgO improved the superconducting properties and transport critical current density of bulk Tl1212 [8]. Besides, other Tl-1212 system with addition of nanosize MgO particles such as $Tl_{0.9}Bi_{0.1}Sr_{1.95}Ta_{0.05}Ca_{0.9}Y_{0.1}Cu_2O_7+x$MgO with x=0.2 was recorded with highest $T_{c\ zero}$ (80 K) but for higher x, $T_{c\ zero}$ was gradually suppressed [9]. In this paper, we report on the effects of variation nanosized calcium oxide on the superconductivity in the Tl-1212 system.

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EXPERIMENTAL DETAILS

The derivatives of Tl-1212 type phase superconductors with nominal starting compositions $Tl(Sr_{1.5}Yb_{0.5})Ca_yCu_2O_{7-\delta}$ for y = 1.0 – 1.4 have been prepared using the solid state reaction and precursor method. High purity oxide (≥99.9%) of SrO, CaO, Yb_2O_3 and CuO were mixed in appropriate amounts and heated at 900ºC for 24 hours with several intermittent grindings. The size of the CuO was <160nm. The heated precursor were then mixed completely with appropriate amounts of Tl_2O_3 and then pellets of 13 mm diameter and 3 mm thickness well pressed. The pellets were heated at 1000ºC in flowing O_2 followed by oven cooled.

The samples were characterized by d.c. electrical resistance with the 4-point probe method. X-ray diffraction using a Siemen D 5000 diffractometer with Cu-K_α source was employed to determine the phase of the samples. The volume fractions of 1212 and 1201 phase were estimated by assuming that the amounts of 1212 and 1201 phases are proportional to the strongest diffraction line of each phase, i.e the (103) reflection of the 1212 phase and the (102) reflection of the 1201 phase. The scanning electron micrographs were recorded using a Philips XL Scanning Electron Microscope (SEM).

RESULTS AND DISCUSSION

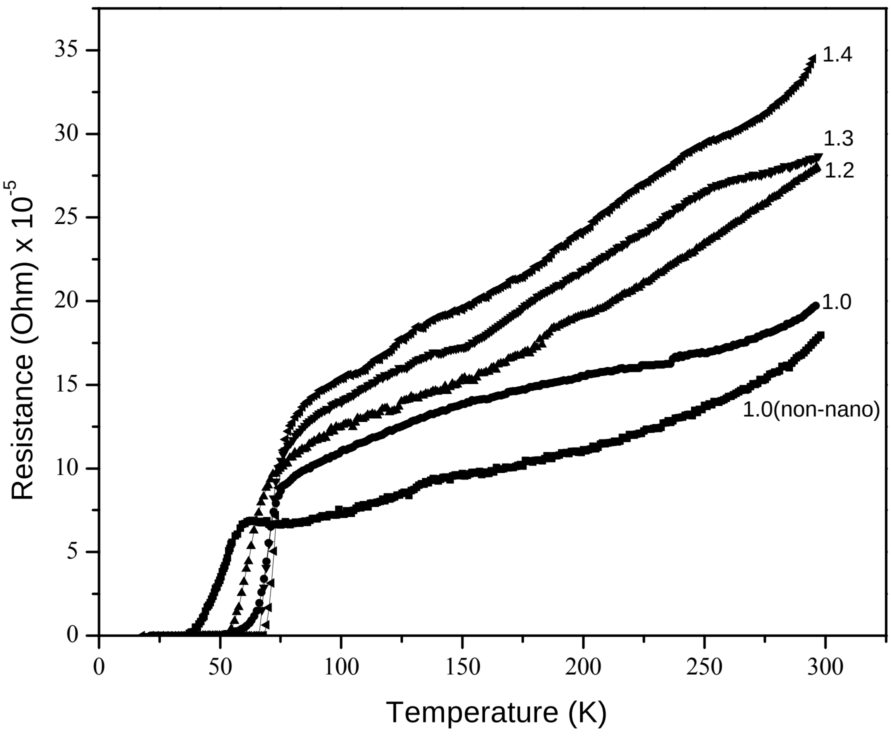

Figure 1: The electrical resistance versus temperature curves

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In this work, $T_{c\ zero}$ is defined as the temperature where the resistance becomes zero and $T_{c\ onset}$ is defined as the temperature where there is a sudden drop in resistance. The critical temperatures were obtained for all samples and $T_{c\ zero}$ values up to 68 K for samples y = 1.0, 1.2, 1.3 and 1.4 (Figure 1 and Figure 2). The curve for y = 0.1 with micro size CaO was also included for comparison. This system showed a metallic normal state behavior for all samples. $T_{c\ zero}$ of the samples showed the increasing trend as the composition of y increases indicatings that the higher composition of nanosized calcium oxide improved the superconductivity of Tl-1212 system.

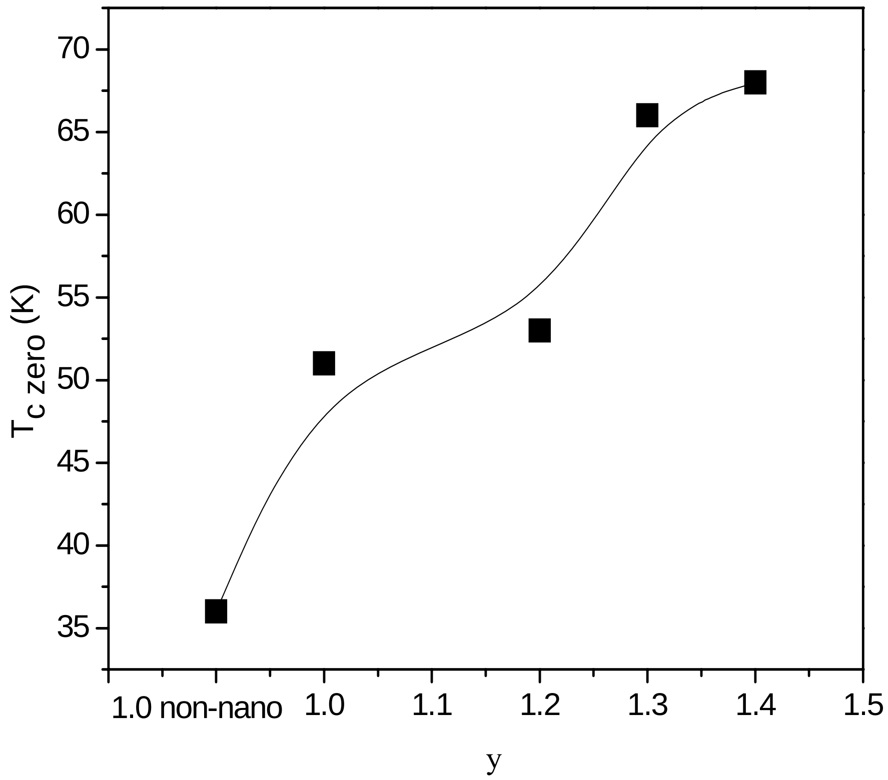

Figure 2: $T_{c\ onset}$ as a function of composition y

The Tl-1212 phase was dominant for 1.0 – 1.4 and was indexed based on a tetragonal unit cell with space group P4/mm. Table 1 shows the percentages of 1212:1201 phase ratio of the system. Most of the samples showed the Tl-1212 as the major phase and 1201 as the minor phase with the percentage about 86% Tl-1212 phase and 14% Tl-1201 phase (Figure 3).

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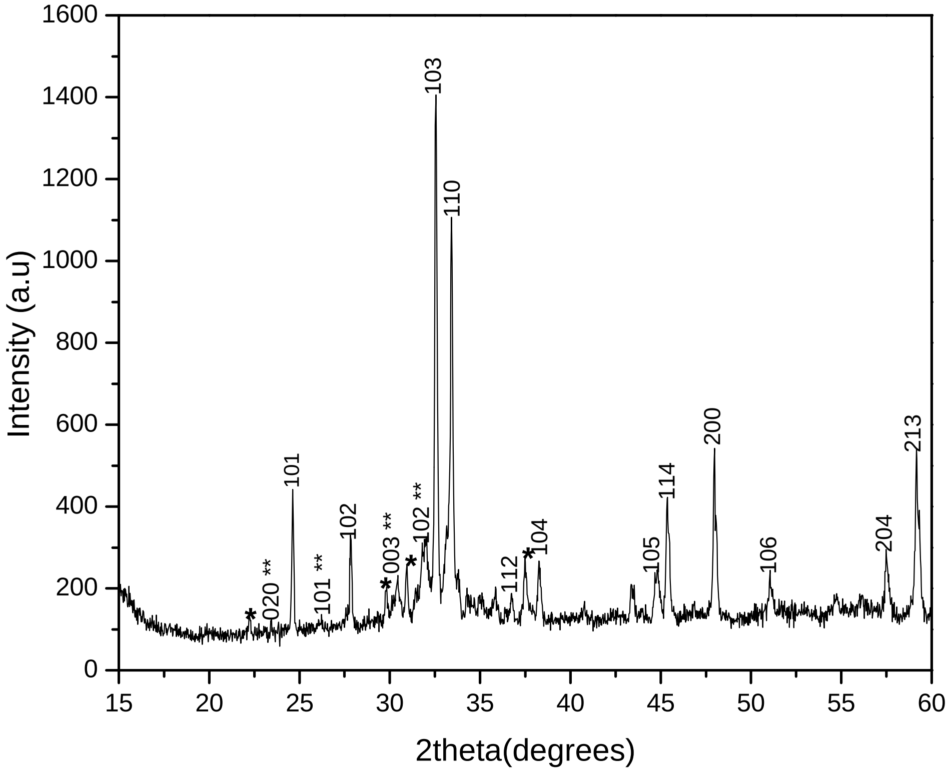

Figure 3: XRD pattern with composition $Tl(Sr_{1.5}Yb_{0.5})Ca_{1.3}Cu_2O_{7-\delta}$ showing the majority 1212 phase. $*Ca_{0.2}Sr_{0.8}CuO_2$, **Tl-1201

Table 1: Percentage of 1212:1201 phase ratio

y	Tl-1212(vol%)	Tl-1201(vol%)
1.0 non-nano	80	20
1.0	83	17
1.2	83	17
1.3	90	10
1.4	87	13

Scanning electron micrographs indicate a similar grain size for all samples which is approximately 2-4 μm (Figure 4(a) and (b)).

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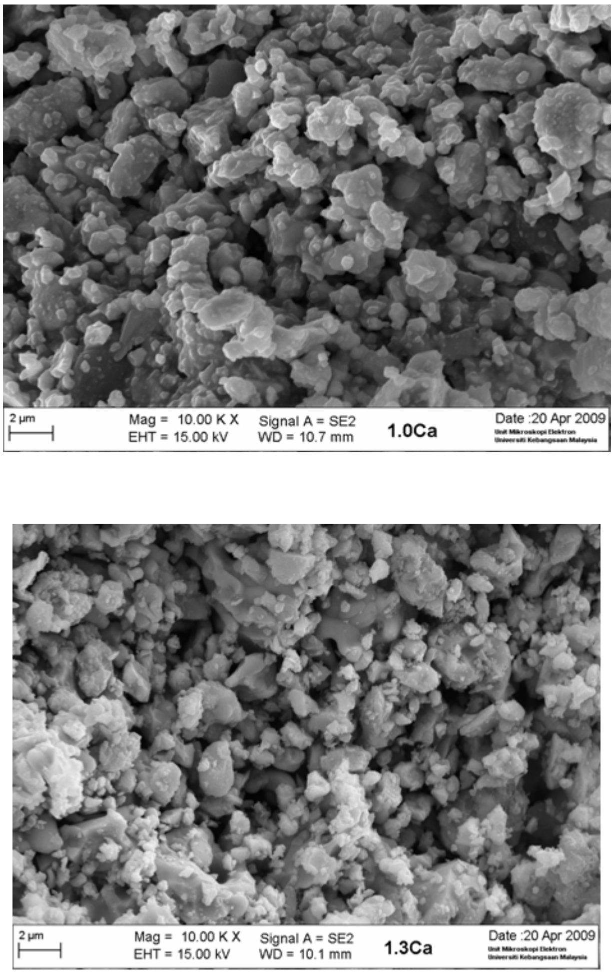

Figure 4: SEM micrographs of $Tl(Sr_{1.5}Yb_{0.5})Ca_yCu_2O_{7-\delta}$ for (a) y=1.0 and (b) y= 1.3

CONCLUSION

In conclusion, nanosized calcium oxide stabilizes the Tl-1212 phase and improves the superconducting behavior. High percentage of nanosized calcium oxide does not change the major phase 1212. Effect of higher nano CaO content on the Tl-1212 system is an interesting research for further investigation.

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