



EFFECT OF BI SUBSTITUTION ON THE SUPERCONDUCTING PROPERTIES OF $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+\delta}$ SYSTEM

Amal K. Jassim, Maysoon F.A. Alias & Muna M. Abbas

University of Baghdad, College of Science, Physics Department

*Corresponding author email: amelalmalki1974@yahoo.com

ABSTRACT

This study was to investigate the effect of Bi doping in the Tl-2223 superconductor by preparing a series of samples (at 860°C for 3h) with complete stoichiometry $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+}$ with x ranging from 0 to 1. The superconducting properties of the samples have been examined by electrical measurements and DC magnetization measurements. It is found that a partial substitution for Tl by Bi decreases the formation of high $-T_c$ phase and decreases its T_c . XRD pattern analyses have shown a tetragonal structure, and there are at least two superconducting phases.

KEYWORD:- TBCCO System, Superconductor, microstructure properties, Sintering Temperature.

INTRODUCTION

Tl-based cuprate superconductors with high critical temperature (T_c) discovered by Maeda *et al.*^[1] and Sheng and Hermann^[2] respectively. Doping with various elements has been found to be useful and effective in improving its properties^[3]. Two superconducting phases, $Tl_2Ca_2Ba_2Cu_3O_{10+}$ and $Tl_2Ca_1Ba_2Cu_2O_{8+}$ were identified in their samples by Hazan *et al.*^[4]. They found that these phases have a pseudo tetragonal unit cell (5.40×5.40×36.25) Å, correspond to a, b and c lattice dimensions, respectively. Dou *et al.*^[5] studied superconducting properties of Tl-Ba-Ca-Cu-O ceramics prepared by a solid state reaction under optimum conditions (880°C sintering in flowing O_2 for 3h). The resistivity, AC susceptibility, and Meissner effect were measured. The temperature-dependent resistivity of $Tl_2Ba_2Ca_2Cu_3O_{10+y}$ showed a degradation in T_c after increasing the sintering time from 3h to 6h and the temperature dependent AC susceptibility showed that at zero applied field the superconducting transition is reasonably sharp with $T_c=110K$.

Jia *et al.*^[6,7] reported on the effect of substitution of Hg at the Tl sites in the oxygen deficient TlO layer of $Tl_2Ba_2Ca_2Cu_3O_{10+}$ cuprate superconductor. They prepared the samples by the two-step reaction process and they found that partial substitution of Tl^{3+} with Hg^{2+} in $Tl_2Ba_2Ca_2Cu_3O_{10}$ produces a stable Tl-2223 phase with the highest possible T_c and claimed that at room temperature the Hg-doped samples have a higher resistivity than the undoped specimen.

Bulk polycrystalline $Tl_2Ba_2CaCu_2O_x$ system has been fabricated by Ossandon *et al.* (2001)^[8], results showed that the crystalline unit cell is tetragonal with lattice constant $a=3.8550\text{Å}$ and $c=29.318\text{Å}$ (cell volume of $2.18\times 10^{-23}m^3$) containing two sets of adjacent oxygen copper layers. The samples were irradiated at room temperature in air with 0.8 GeV protons. The superconductive properties of the virgin and irradiated materials were investigated magnetically. Single crystals of TBCCO (Tl-2212) have been grown from a stoichiometric mixture of Tl_2O_3 and a

precursor $Ba_2CaCu_2O_x$ prepared by Chowdhary *et al.* (2002)^[9]. They observed that the transition temperature $T_c=105K$ and the transition width T_c was around 5K, as determined from the temperature-dependent magnetization (MT) measurements, at a field of 10G.

Kareem and Tariq^[10] have investigated the effect of simultaneous substitution of strontium at the barium site of $Tl_{0.6}Pb_{0.4}Ba_{2-x}Sr_xCa_2Cu_3O_{9-}$ Superconductors and found that $T_{c(off)}=113K$ for $Tl_{0.6}Pb_{0.4}Ba_{1.5}Sr_{0.5}Ca_2Cu_3O_{9-}$. Khan *et al.*^[11] have studied the enhanced Inter-grain Connectivity in $(Cu_{0.5}Tl_{0.5})Ba_2Ca_2Cu_3O_{10-}$ Superconductors.

Masoon *et al.*^[12] investigated the effect of sintering temperature and time on the transition temperature for $Tl_2Ba_2Ca_2Cu_3O_{10}$ and $Tl_2Sr_2Ca_2Cu_3O_{10+}$ systems type 2223 and studied the effect of these parameters on the structural and electrical resistivity of both prepared systems. They found that for Tl-2223 system, the T_c increased and decreased with increasing sintering temperature and time respectively. Discoveries of Tl-based system have not only set new T_c records with zero resistance up to 125K, but also have provided a new insight into the mechanism of high- T_c oxide superconductivity^[11]. In this paper we investigated the effect of Bi doping on the electrical and structural properties of $Tl_2Ba_2Ca_2Cu_3O_{10}$ system type 2223.

EXPERIMENT

The solid state reaction technique has been used to prepare homogeneous and well-defined single phase superconducting samples with uniform oxygen stoichiometry evolution of accurate physical parameters. Precursor $Ba_2Ca_2Cu_3O_{10+}$ were first prepared using high purity powders of $BaCO_3$, CaO and CuO as starting materials. Then, Tl_2O_3 and Bi_2O_3 were added to the mixture and grinding them in agate mortar for about 30 min to obtain a very fine and optimum homogenous powder. The mixtures were pressed into a pellet of (0.2-0.3) cm in thickness and 1.3cm in diameter, under a pressure of about 3 ton/cm². The samples were sintered in air atmosphere of 860°C for

3h. The resistivity measurements were carried out by the four probe method with 30mA current. The structure of the prepared samples was obtained by using x- ray diffractometer (XRD) type Philips having the following features (source : Cu_k ,voltage : 40kv , current : 20 mA, wavelength : 1.5405 \AA). Magnetization data have been taken in an automatic magnetometer (VSM 3001). For magnetization measurements, 50 Oe magnetic field has been applied

RESULTS & DISCUSSION

The finding showed that the substitution of Bi instead of Tl, at different values of x (0-1), forming a variety of $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+}$ compounds; the results are shown in Fig. (1) and Table (1). It is found from this figure that the behavior of resistivity with temperature for the composition with x=0, 0.1 and 0.2 is a superconductor

with $T_c=120,115$ and $110K$, respectively. Increasing Bi to x= 0.3 and 0.4 decreases the transition temperature to $T_c<77K$, it was expected, (if we use liquid He for cooling). While that for x 0.5 the compound becomes a semiconductor (see Fig.1). The results could be explained as follows; a small amount of Bi substitution is quite effective in the destruction of the high- T_c phase (2223) and it enhances the formation of low- T_c phase (2212) of TlBaCaCuO superconductor system. This result is consistent with XRD analysis. Similar results were mentioned by Torii et al ^[13] who found that a partial substitution of Bi for Tl in the $Tl_1Ba_2Ca_2Cu_3O_9$ system sintered at $865^\circ C$ to $870^\circ C$ in oxygen flow for 12h, causes an initial gradual decrease in the critical temperature and the disappearance of superconductivity beyond a 50% substitution.

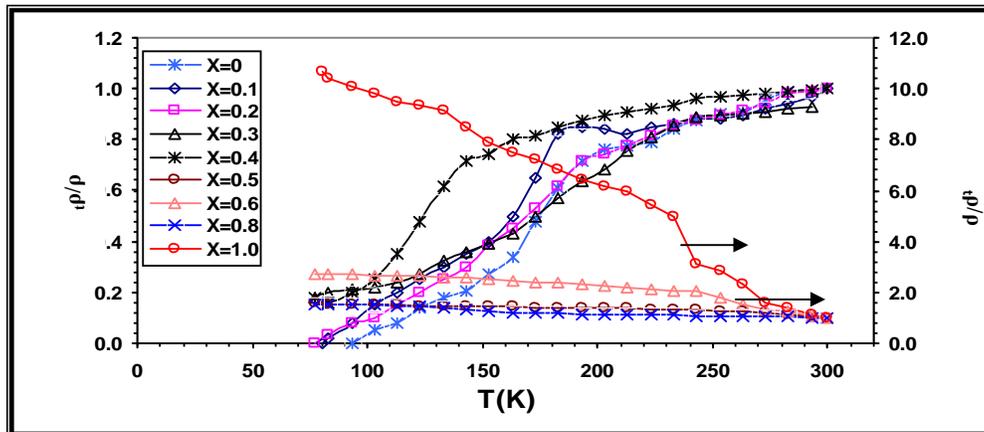


FIGURE 1: Temperature dependence of normalized resistivity for $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+}$ system with different Bi content

The magnetization (M) for $Tl_{1.8}Bi_{0.2}Ba_2Ca_2Cu_3O_{10+}$ has been measured at different temperature (from 80 to 160K) and is shown in Fig. (2). It displays an abrupt transition

whose temperature is in an excellent agreement with that determined from the transport data.

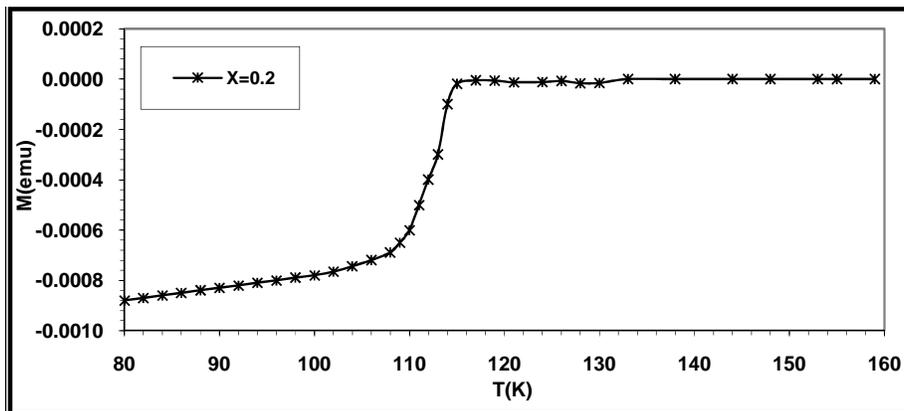


FIGURE 2: Variation in magnetization with temperature for $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+}$ compound

The x-ray diffraction patterns of Bi-doped Tl-based superconductor for $x < 0.5$ have been taken for x=0 and 0.1, the peak positions intensities of the diffraction data have revealed that our sample mainly consists of the Tl-2223 phase^[14] and a small amount of Tl-2212 phase as a minor phase together with some other unidentified peaks

.The increase of Bi content (x= 0.2 ,0.3 and 0.4) leads to enhance a low- T_c phase, as well as, the crystallinity of the high phase becomes less. These results indicate that the doping by Bi may well relax the modulation by influencing the charge balance. Although the oxygen content increases but it shows the degradation in the high

T_c phase because of the super electron density in the structure of the relevant layer was low enough to degrade T_c . This yielded a reduction in the T_c value, and a partial phase transformation from Tl-2223 to Tl-2212. More doping by Bi has created more local structure distortions specially within the Cu-O planes because of the remarkable difference in ionic radii and hence it becomes

not possible to obtain high- T_c phase. This can be inferred from the x-ray diffraction in Figs. (3a, b & c) and (4a & b). The data of the critical temperature and the variation of the c-lattice parameters of these doped samples are listed in Table (1) and Fig. (5). We can see from this figure the reduction of the c-axis lattice constant with the increasing Bi content.

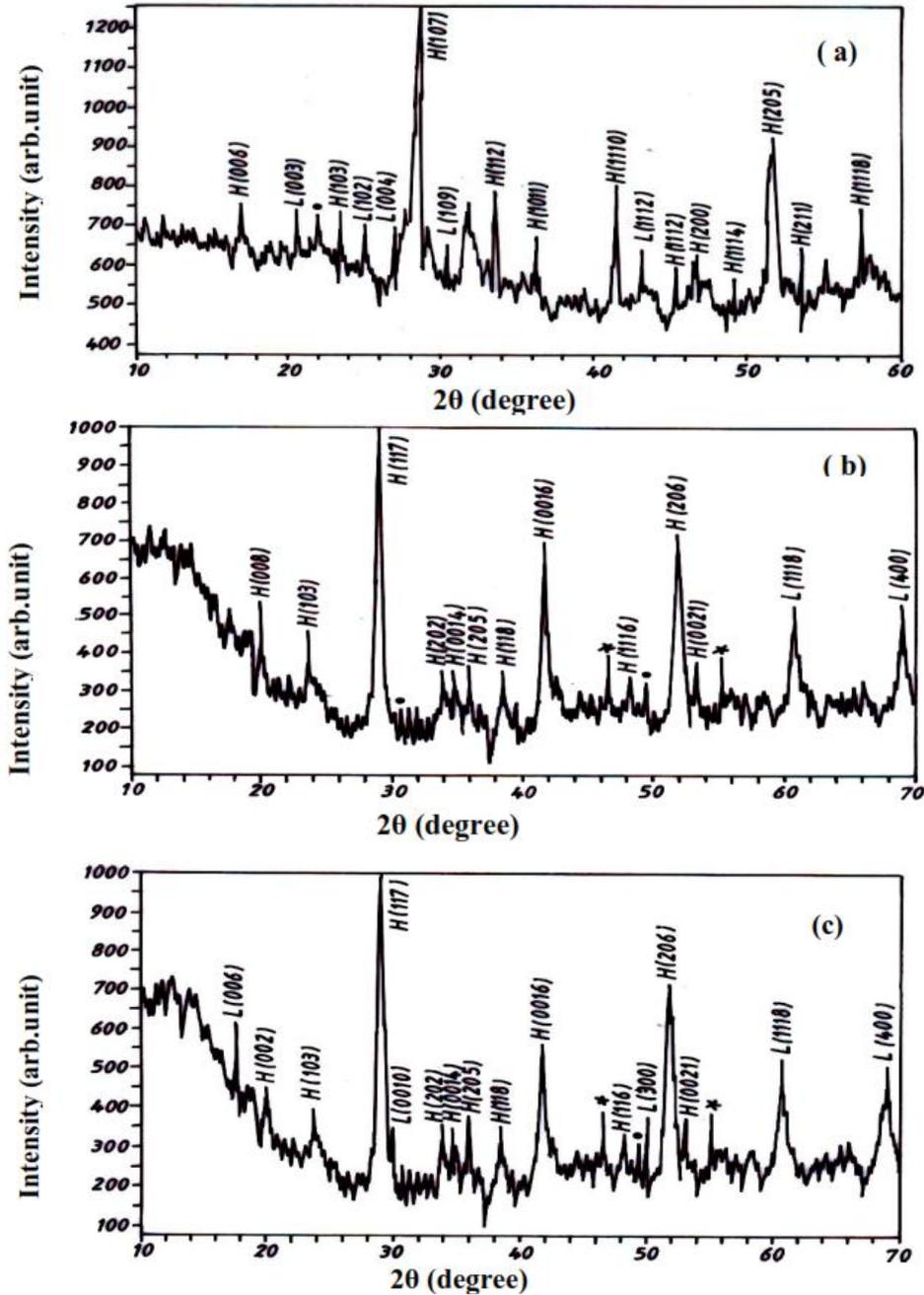


FIGURE 4: X-ray diffraction patterns for the $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+}$ samples (a) $x=0.3$, (b) $x=0.4$. H-High T_c phase and L-low T_c phase respectively, .-impurity phase $BaCuO_2$, #-impurity phase Ca_2CuO_3 , *-unknown impurity.

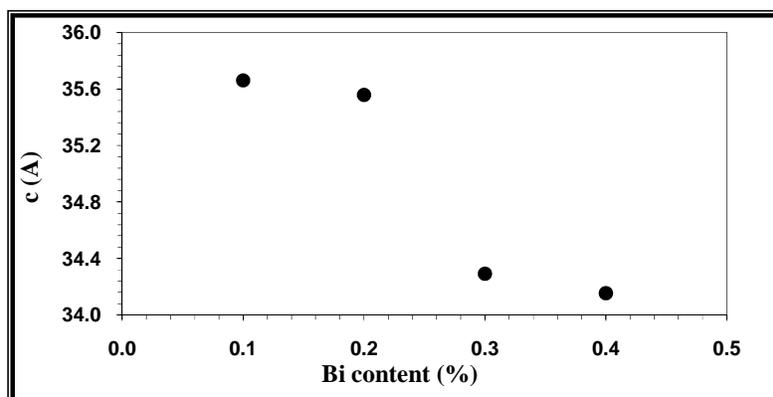


FIGURE 5: Variation of the c-axis lattice constant with Bi content for $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+6}$ system

TABLE 1: Variation in T_c values, lattice parameters and oxygen content for different compositions of $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10+6}$ system sintered at $860^\circ C$ for 3 hours

| x | a(Å) | c (Å) | T_c (K) |
|-----|-------|--------|-----------|
| 0 | 3.849 | 35.500 | 120 |
| 0.1 | 4.530 | 35.662 | 115 |
| 0.2 | 4.549 | 35.558 | 110 |
| 0.3 | 4.101 | 34.293 | <77 |
| 0.4 | 4.122 | 34.155 | <77 |

CONCLUSION

The outcome foundation of above data is the following:

1. A partial substitution for Tl by Bi decreases the formation of high $-T_c$ phase and decreases its T_c .
2. The magnetization examination confirmed the electrical investigation and showed a second order transition as evidence that our 2223 HTSc is of type II.
3. XRD pattern analyses have shown a tetragonal structure, and there were at least two superconducting phases.

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