Study the partial substitution for Sr at the Ba on the properties of 
$\text{Tl}_{1.6}\text{Hg}_{0.4}\text{Ba}_{2-y}\text{Sr}_y\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ superconductors

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Abstract. In the present study we have reported realization simultaneous effect substitution of strontium at the barium layer of $\text{Tl}_{1.6}\text{Hg}_{0.4}\text{Ba}_{2-y}\text{Sr}_y\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ superconductor. Samples of bulk polycrystalline have been prepared by the reaction of solid state process. Four probe technique, is used to find the transition temperature $T_c$. It was found that the critical temperatures at zero resistivity $T_c(\text{Offset})$ are $95$, $115$ and $125$K and $T_c(\text{on})$ were $45$, $40$ and $45$K for $\text{Tl}_{1.6}\text{Hg}_{0.4}\text{Ba}_{2-y}\text{Sr}_y\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ with $y = 0$, $0.1$ and $0.2$ respectively. The X-ray diffraction study showed that all prepared samples have tetragonal structure, with a clear change in the constants of lattice with strontium-substituted samples compared to this without strontium. It has also been found that a change in the concentrations of strontium leads to a change in, $c / a$. $\text{Tl}_{1.6}\text{Hg}_{0.4}\text{Ba}_{2-y}\text{Sr}_y\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ phase development was observed. The surface morphology studied for prepared specimens using atomic force microscopy (AFM). It was found that the average grain size and surface change with the change of the rate of dopant.

Key word: Simultaneous substitution, Superconductor, Bulk polycrystalline, Electrical resistivity, lattice constant and Atomic force microscopy.

1. Introduction

The $\text{TlBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{6+\delta}$ (1223) phase compound has a transition temperature, $T_c$ equal to $112$ K and is the first reported superconductor configuration among its analogues, with a superconductor$[1,2]$. This compound is known as one of the $\text{TlBa}_2\text{n}\text{Cu}_n\text{O}_{2+n}$ series of monolithic compounds, where $n$ is the number of Cu-O layers, has found a structural arrangement of perovskite and rock salt layers. It has a tetragonal with lattice parameter $a = (3.847 \text{ Å})$ and $c = (15.89 \text{ Å})$ $[4-6]$. Stability of the stage for this compound was also studied $[7-9 ]$, most of the properties, processes, thin-film processing and classification of other high-temperature superconductors in this series contain the phase (2212, 2223, 2234, 1234)$[10-12]$. All of these phases are of commercial importance, because $T_c$ has a high value (above $125$ K) much higher than $\text{Ba}_2\text{YCu}_3\text{O}_{6+\delta}$ (90 K) and $\text{Bi-Sr-Ca-Cu-O}$ compounds (above 110 K). Several replacement variations for the $\text{Tl-Ba-Ca-Cu}$ oxide phase (1223) were studied. Matsuda et al prepared the $\text{TlSr}_2\text{Ca}_2\text{Cu}_3\text{O}_8$ compound and found that its transition temperature was (100 K) $[11]$. Although the single-phase of $\text{TlSr}_2\text{Ca}_2\text{Cu}_3\text{O}_8$ phase is difficult to prepare, the liquid phase synthesis technique reported by Morgan et al. $^1$, Has brought some success. The stability and properties of this phases (1223) can be significantly improved by partial substitution of lead and / or bismuth of thallium in the rock salt layer $[13-17]$. Most treatment processes include the solubility phase, either as an equilibrium product or as a transient fluid. The information needed to melt the equilibrium in phase (1223) is critical for processing. Only a few studies on fusion were investigated in $\text{Tl-Ba-Ca-Cu-O}$ and related systems (1223), possibly due to instability. Blaugher $[18]$ reported the melting scheme of the graphs based on the data that could be
obtained, but included only the thallium double compounds. Melting peristalsis of non-alternative (1223) reported in 905°C in oxygen [19]. Melting products included BaCuO$_2$ and CaO. In addition to solubility, the main factor is the control or control of thallium pressures through processing. Many systems contain (1223) where six or more components are currently relevant, creating a need for accurate data regarding thallium pressures for multi-component installations. Holstein performed a measure of thallium pressure on pure Tl$_2$O$_3$, which is the basis on which pressure can be compared in other systems [20,21]. It also provides a method for controlling thallium pressure, using a method known as “two zones” used by Kareem Ali Jassim [5]. They have reported a stabilization zone of "1223" in terms of the PTl$_2$O$_3$, PO$_2$ and temperature variables. In this article we synthesis the Tl$_{1.6}$ Hg$_{0.4}$Ba$_2$-$_y$Sr$_y$Ca$_2$Cu$_3$O$_{10+δ}$ superconducting specimens reaction by substituting an amount of Sr by Ba with $y = 0.0, 0.1$ and 0.2 through a solid-state reaction.

2. Experimental

Specimens of bulk Tl$_{1.6}$ Hg$_{0.4}$Ba$_2$-$_y$Sr$_y$Ca$_2$Cu$_3$O$_{10+δ}$ compound with $y = 0.0, 0.1$ and 0.2 were synthesized through a solid state reaction. Suitable amounts were weighed in equal proportions of high purity powders, HgO, Tl$_2$O$_3$, AgO, CaO, BaO and CuO, where they were ground in an agate mortar. The grinding powders were sieved by sieving 100 μm. The powder is compressed Pressure (8 ton/cm$^2$) in the form of a disc diameter (1.2 cm) and a thickness of (0.2 to 0.3 cm). The sample was then wrapped in a silver sheet to reduce the potential volatility of (B and Sr) which could eventually interact with the small quartz tube furnace.

The samples were heated by a rate of 120 °C / h from room temperature until reaching 850 °C(Tikrit Hospital) and the samples were kept at this temperature for 24 hours and then were cooled at rate 120 °C / h to 600 °C stays at this temperature for 12 hr with oxygen injected into the furnace. The temperature was decreased from 600 °C to room temperature at a rate of 30°C / h.

Characteristics of the resistivity ($\rho$) as a function of temperature T of these Specimens were measured by means of a standard d.c four-probe technique to investigate their superconducting state. The crystallographic structure of the prepared samples was obtained using XRD measurements within the range of (20 to 80) degrees. lattice constants parameters (a) and (c) calculated from the relationship [22]:

$$\frac{1}{d^2} = \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2} \quad \text{(1)}$$

Where $h, k, l$ is Miller indices, $d$ (hkl) is the inter planer distance for different planes.

3. Results and discussion

Compositions of Tl$_{1.6}$ Hg$_{0.4}$ Ba$_{2-y}$Sr$_y$Ca$_2$Cu$_3$O$_{10+δ}$, with $y = 0.0,0.1,0.2$, the phases were well established by X-ray diffraction analysis. Figure 1 shows the X-ray powder diffraction patterns for 2223 phases prepared in the laboratory (Baghdad University Ibn -Al Haytham College).

The positions and intensity of diffraction peaks reveal that samples consist mainly of a major phase 2223. The parameters of the lattice were calculated using the values of $d$ and reflections (hkl) of the observed X-ray diffraction pattern and through the reflection angles (20) has been found Miller coefficients, according to the source[22] (hkl) and using the equation (1).
The parameters obtained a, b, c and ratio (c / a), show the tetragonal structure symmetry of all our samples. The c parameter, ratio c/a and volume of the unit cell are significantly increasing with the increase of strontium concentration.

This is due to the Sr substitution for Ba where the radius of Sr$^{+1}$ ions is longer than Ba$^{+2}$, which makes the c parameter longer or becomes distorted. Thus, the size of the volume of lattice becomes larger. This explains the reason for the increased transmission. These results are almost identical to those reported in references[13]. The variation of resistivity with temperature of the as synthesized Tl$_{1.6}$ Hg$_{0.4}$ Ba$_{2-y}$Sr$_{y}$ Ca$_2$Cu$_3$O$_{10+\delta}$ samples was measured by the standard four-probe technique. The normal state resistance of all the samples shows metal like behaviour with respect to temperature. A plot of the normalized resistivity vs temperature ($\rho$–$T$) behaviour of samples with various Tl concentrations are shown in figure 2. Table 1 summarizes the lattice parameters, critical temperature onset “Tc(onset)”, zero resistivity temperature offset “Tc(offset)” and transition width $\Delta T$ 2223 thallium copper oxides.

Table 1. Values of transition temperature Tc(offset), Tc(onset) and lattice parameters for Tl$_{1.6}$ Hg$_{0.4}$ Ba$_{2-y}$Sr$_{y}$ Ca$_2$Cu$_3$O$_{10+\delta}$, with y = 0.0, 0.1, and 0.2.

| $Y$ | T$_{c(off)}$(K) | T$_{c(on)}$(K) | T$_c$(K) | $a$(A) | $b$(A) | $c$(A) | c/a |
|-----|----------------|----------------|---------|-------|-------|-------|-----|
| 0   | 95             | 145            | 120     | 3.54  | 3.54  | 34.80 | 9.83|
| 0.1 | 115            | 140            | 128     | 3.40  | 3.40  | 34.81 | 10.2|
| 0.2 | 125            | 145            | 135     | 3.17  | 3.17  | 35.15 | 11.08|

Figure 1. The diagram shows X-ray diffraction of Tl$_{1.6}$ Hg$_{0.4}$ Ba$_{2-y}$Sr$_{y}$ Ca$_2$Cu$_3$O$_{10+\delta}$ at indicated values of Sr at “y = 0.0, 0.1 and 0.2”
The figure 2. shows the c parameter, ratio (c/a) are significantly increasing with the increase of Sr concentration. This increases indicate to the partial replacement of Ba atoms by Sr. This is because the ionic radii of Sr is longer than that of Ba, which renders c-parameter to be longer or get deformed.

The values of temperature transition critical (\(T_c\)) for as grown Tl\(_{1.6}\) Hg\(_{0.4}\) Ba\(_{2-y}\)Sr\(_y\) Ca\(_2\)Cu\(_3\)O\(_{10+\delta}\) are 95, 115 and 125 K, respectively. In view of the quality characterization provided by Kareem et al[23], it can be categorically stated that our samples are of ‘good quality’. Since the maximum value of \(T_c\) is expected to be for optimum hole doping, the concentration Tl\(_{1.6}\) Hg\(_{0.4}\)Sr\(_{0.2}\) Ba\(_{1.8}\) Ca\(_2\)Cu\(_3\)O\(_{10+\delta}\) would correspond to
The optimum level of hole doping. [24, 25]. We can see from the figure (4) that the transition temperature \( T_c \) increases with increasing the concentration of Sr, As shown in the figure, the transition temperature on set \( T_{c\text{(on)}} \) increases more than \( T_{c\text{(off)}} \) with increasing concentration of Sr.

![Image of transitional temperatures graph](image-url)

Figure 4. Transitional temperatures (\( T_{c\text{(off)}} \) and \( T_{c\text{(on)}} \)) as a function of Sr for \( \text{Tl}_{1.6} \text{Hg}_{0.4} \text{Ba}_{2-y} \text{Sr}_y \text{Ca}_2\text{Cu}_3\text{O}_{10+\delta} \) for the values indicated at \( y = 0.0, 0.1 \) and 0.2.

Figure 5. represent AFM images 3D of \( \text{Tl}_{1.6} \text{Hg}_{0.4} \text{Ba}_{2-y} \text{Sr}_y \text{Ca}_2\text{Cu}_3\text{O}_{10+\delta} \) superconductor compounds with \( x=(0.0, 0.1\text{and } 0.2) \). We found that there is an imbalance and areas with low nanometer dimensions and high density differ from one location to another within the sample [23]. We observed the presence of different gradients from one sample to another, as well as the average roughness and surface deviation from several locations of the surface and inside the sample as shown in the following figure 5.
4. Conclusions

We have investigated the simultaneous effect of substitution of Sr at the Ba site in the oxygen deficient Tl$_{1.6}$Hg$_{0.4}$Ba$_{2-y}$Sr$_{y}$Ca$_2$Cu$_3$O$_{10+\delta}$. It was found that the transition temperatures increased from 95 to 125 K by increasing barium concentration from 0 to 0.2, respectively. Cuprate superconductor have been prepared under optimum conditions. X-ray diffraction analysis showed all samples have a tetragonal structure corresponding to 2223 phase and an increase of the c-axis lattice constant for the samples doped with Sr as compared with these have no Sr content. The transition temperatures of a growth samples are found to be sensitive to the concentrations of Sr, it has been observed that maximum $T_c = 125$ K is achieved for Tl$_{1.6}$Hg$_{0.4}$Ba$_{1.8}$Sr$_{0.2}$Ca$_2$Cu$_3$O$_{10+\delta}$ where Sr =0.2. The characteristics and information of the surface specimens are recorded through the examination of AFM then we found the best specimen when $x=0.2$ the Avg. Diameter equal 8.3nm.

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