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The effective of partial replacement of barium by Yttrium on $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ superconducting compound

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Abstract. The enhancement of superconductor compounds contribute in reducing the heat pollution that gain from electric transfer. The main focus of all researchers pointed on high temperature superconductors where they aim to get higher critical temperature. This research focus on investigations the concurrent substitution effect Yttrium at the Barium site of $HgBa_2Ca_2Cu_3O_{8+\delta}$ superconductor for x=0, 0.1, 0.2 and 0.3, The samples were prepared using a solid-state reaction technique and all samples were exposed to XRD so as to know the crystal structure and its lattice constants. XRD data collected from different samples showed that represents high critical phase and the analysis presents a tetragonal structure. To find the critical temperature 4 probe technique was adopted using relationship electrical resistance and temperature. It was observed that there was a critical temperature rise with the increase of strontium from 95 K to 120 K.

Keywords: X-ray diffraction, Critical temperature, Tetragonal structure, Superconductors, Critical temperature and Electrical Resistivity.

INTRODUCTION

The superconducting series of mercury compounds is known to be chemical $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ (n=1to 8, Where n represents Cu-O layers) the most interesting homogenous series of superconductors represent a high temperature cuprate, because they have the highest critical temperature T_c [1, 2].The single Cu-O layer has critical temperature of 94 K, Double layers has T_c=127 K and Triple layers of Cu-O has T_c = 135 K . When the sample was prepared under high pressure, the critical temperature increased between 150-160 [3]. All superconducting phases containing copper layers n = 1 to n = 8 for this series have a tetragonal structure cell system and perovskite layers [4]. Structure of the mercury based is approximately the same as the copper and thallium based superconductor with has a single layer of Tl-O, but the most important difference is a Tl-O layers have very few oxygen vacancies, while the Hg-O layers have more oxygen deficient. Oxygen atoms are poorly bound to mercury and their occupancy are likely a vary widely depending on the preparation for different members of the first division have shown symmetric mercury [5, 6]. As the Cu-O layers abound, they are main responsible for the high critical temperature of superconducting materials "[7]. Unfortunately, many problems are still related to stability of the phase, In particular the presence of humidity and carbon dioxide. Many reports show that phase composition and superconductivity properties They are improved by replacing some chemical elements with positive alternatives, Phase formation and Critical current density of Hg-base can be improved in substitution by They are improved by replacing some chemical elements with positive alternatives, Ag, Tl, Sb, Cu, Cd, Zn

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or other elements [8-14]. Measurement of resistivity (ρ) is one of the most important properties of materials, it is the most common way to determine the critical temperature of the superconductor. In this research there are important measurements to study the some properties of the $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ samples, such as X-ray diffraction (XRD) and electrical resistivity.

EXPERIMENTAL

Using a balance sensitive to the weight the powders Oxides of mercury, yttrium, barium, calcium and copper Prepare samples with chemical formula $HgBa_{2-x}Sr_xCa_2Cu_3O_{8+\delta}$, at x = 0,0.1,0.2,0.3 using solid of state reaction technique, after weighing each reactant separately, to homogenize and using agate mortar mixed powders together. The mixture was then grinded for 40 minutes using a magnetic stirrer. The powder was compressed as a disc with a 15 mm diameter of and a 3 mm thickness, Compressed under pressure 8 MPa using hydraulic press for 1 min. The pellets were sintered at (860) ° C for 28 hours using a furnace with a 5 ° C / min heating rate and then cool to temperature of the room with the same rate of heating.

The structures of crystal for the $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ samples prepared was obtained using Shimadzu X-ray diffraction diffractometer which has the following features: Wavelength: 1.5405A^0, Radiation source: Cu Kα, Voltage: 40.0 (kV), Current: 30.0 (mA), scan of speed is a 8(deg/min) and 2θ range: 20-80(deg). Lattice parameters c, a and b were calculated using computer software (Full Prof), its details are mentioned in the references [9, 10]. And extruding the XRD peaks of the high phase Hg-Base volumetric fraction ratio was calculated by using the following formula [15]:

$$V_{PH} = \frac{\sum I_0}{\sum I_0 + \sum I_1 + \sum I_2 + \sum I_3 + + + \sum I_{other}} \times 100\% \quad \ldots\ldots\ldots\ldots 1$$

$$\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where peak indensity I_o of the stage to be calculated, I_1, I_2, I_{other} are intensity of peaks for all XRD. The mass densities (d_m) were calculated using the equation [11].

$$d_m = W_m / N_A V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Weight of the molecular W_m, Avogadro's number N_A and volume of unit cell V.

The resistance as a function of temperature (by using 4-point probe) is a most common method for determining and calculating the critical temperature of superconducting using the temperature range (77-300K),

Samples were placed in a cryostat that was connected by rotary pump to empty the air in the chamber to obtain pressure 6 $x10^{-2}$ mbar in cryostat, and It also joined the digital thermometer sensor near sample location. The presence of copper wire attached to sample which Place in the oven after the electrodes are fixed with a silver paste as a threaded voltage and current leads (Figures (1). A 20 mA current was supplied to the sample is powered by a DC source; Voltage drop in nanometer (voltmeter) was measured with a sensitivity approaching nanometer for measurements of voltage. The electrical resistivity (ρ) can be calculated from the relationship: $\rho = \frac{V}{I}\frac{\omega t}{L}$ Where: I a current goes through the sample, V: a voltage difference across electrodes, ω: sample width, L: Distance between electrodes, t: represent to sample thickness.

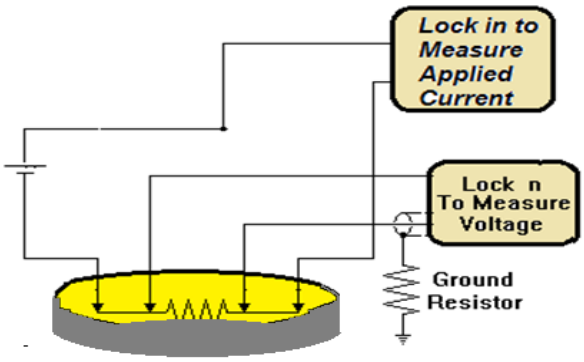

Figure 1. represents a chart diagram for measuring resistance

RESULT AND DISCUSSIONS

The XRD of intensity patterns - 2Θ of $HgBa2_{-x}Y_xCa_2Cu_3O_{8+\delta}$ compound x= from 0 to 0.3 as show in figure 2 (B. C and D), While relative intensity reflections of pure sample is show in figure 2 (A) and table. Table show changing in c lattice parameters, The reason for the replacement is Y for Ba where the radii of ionic for Ba^{+2} [r =1.35 A^0)] longer than the radius of strontium [Y^{+2}(1.12 A^0)] leading to expansion of the Hg-O base structure (a and b) leading to a decrease in length c. Figure 3 represented the volume fraction as a function of Y concentration it was shown from this figure that the increasing in Yttrium concentration produced increased in volume fraction.

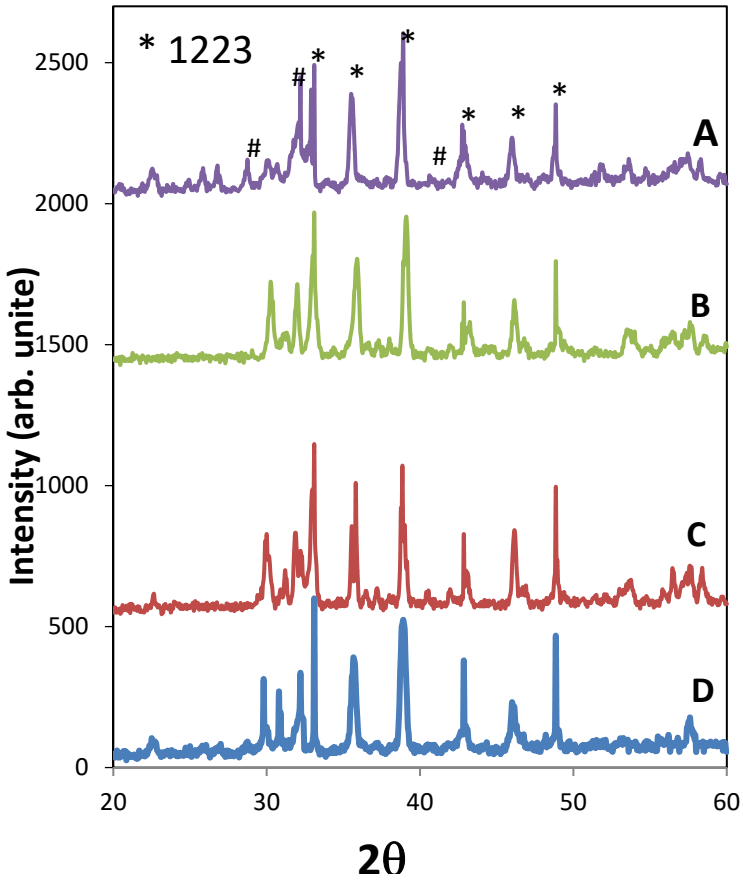

Figure 2. Represents the X-ray diffraction pattern of $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ system with x= 0, 0.1, 0.2 and 0.3

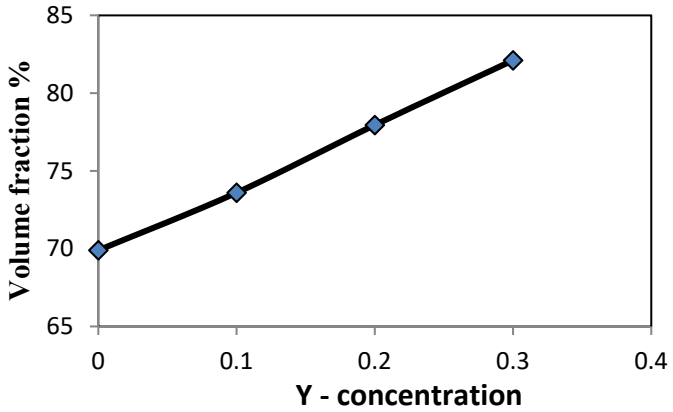

Figure 3. Relationship of volume and Y concentration of $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ with x= 0 t0 0.3

Figure 4. show the electrical resistivity as a function of Temp. for pure samples, where that the critical temperature are determined from it [14]. From figure (3-A), It is noted that the electrical resistance at first drop represents $T_{c(onset)}$ (transition from normal to superconductors) is approximately 113 K and A critical temperature of zero resistance $T_{c(onset)}$ was observed at 95 K. And the value change in the width of transition (ΔT=18). When Yttrium oxide (Y_2O_3) substitution in Barium oxide for $HgBa_{2-x}Y_x$ $Ca_2Cu_3O_{8+\delta}$ specimens (x =0.1, 0.2, 0.3) are shown in figure (3-B, C and D), from all curves there is a transition from normal to superconducting. Values of critical temperature at zero of resistivity $T_{c(offset)}$ for $HgBa_{1.9}Y_{0.1}$ $Ca_2Cu_3O_{8+\delta}$, $HgBa_{1.8}Y_{0.2}$ $Ca_2Cu_3O_{8+\delta}$ and $HgBa_{1.7}Y_{0.3}$ $Ca_2Cu_3O_{8+\delta}$ are 107,113 and 120 K and critical temperature at onset resistivity $T_{c(onset)}$ are 120, 129 and 133 K and change in the width critical of (ΔT=17, 15 and 13) respectively, The highest critical $T_{c(offset)}$ was 120 K for $HgBa_{1.7}Y_{0.3}$ $Ca_2Cu_3O_{8+\delta}$, where show a raise the critical temperature with raise yttrium concentration, Thus fraction of volume increases, but density of mass decreases with raise yttrium concentration as shown in Fig. 5 and Table.

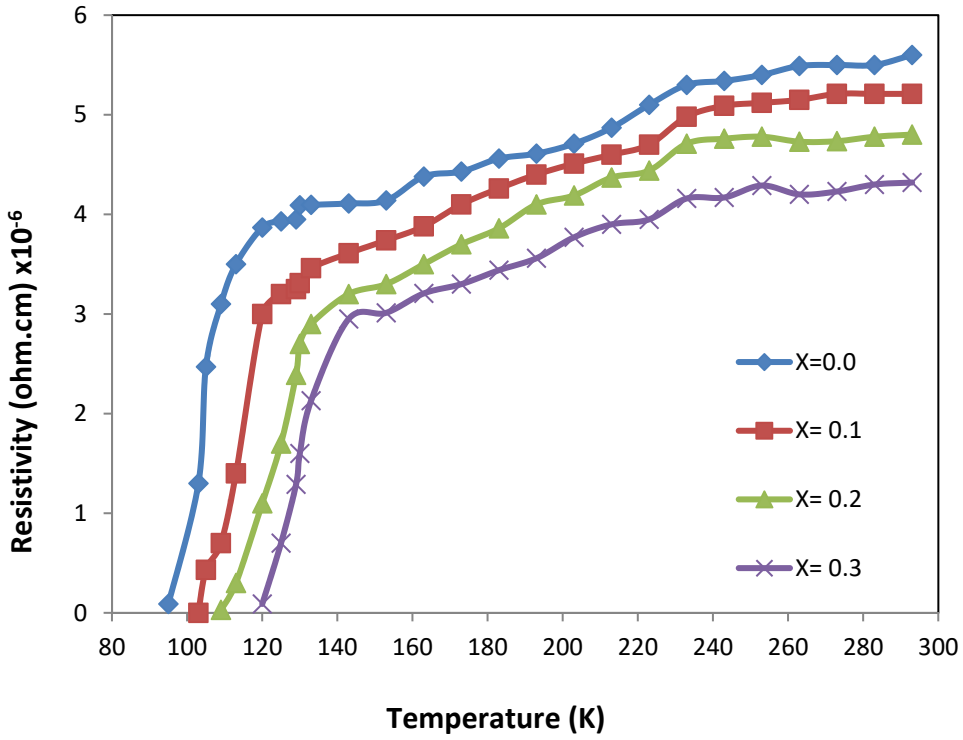

Figure 4. Temperature dependence of resistivity for $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ samples with x= 0 to 0.3

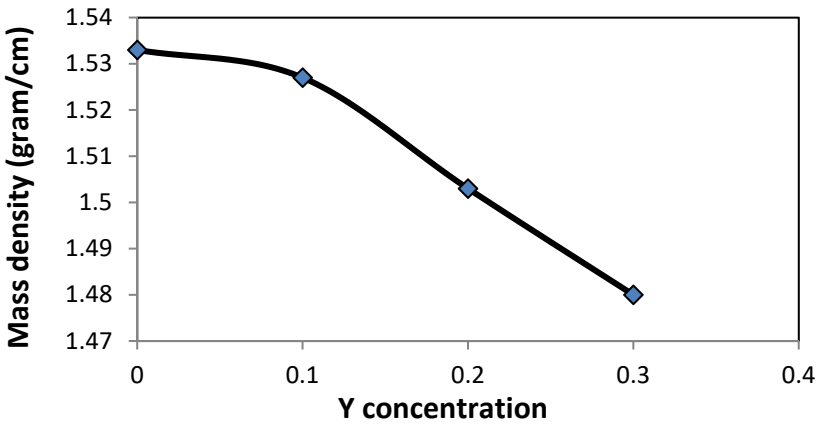

Figure 5. Mass density dependence of Yttrium concentration for $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ samples with x= 0 to 0.3

Table 1. Values of both critical temperatures, lattice constant (a, b, c, c/a), mass density ρM and volume fraction for the $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ system with x= from 0 to 0.3

X	$T_{c(off)}$*(K)*	$T_{c(on)}$ *(K)*	$a(A^0)$	$b(A^0)$	$c(A^0)$	*c/a*	ρ_M *(g/cm³)*	$V_{Ph\text{-}1223}$%
0.0	**95**	**113**	**3.842**	**3.84**	**15.75**	**4.099**	**1.533**	**69.913**
0.1	**103**	**120**	**3.832**	**3.83**	**15.35**	**4.006**	**1.527**	**73.651**
0.2	**114**	**129**	**3.8456**	**3.84**	**15.38**	**3.999**	**1.503**	**77.932**
0.3	**120**	**133**	**3.392**	**3.39**	**15.44**	**4.102**	**1.481**	**82.111**

CONCLUSIONS

In this article, the $HgBa_{2-x}Y_xCa_2Cu_3O_{8+\delta}$ high-Tc superconducting compounds was prepared. The effect of replacement of yttrium oxide at Ba site of Ba-O_2 layer was investigated for $HgBa_2Ca_2Cu_3O_{8+\delta}$ particular emphasis is placed on the relationship between substitution of inputs in the compound and their effect on structural and electrical properties. The data of XRD collected for different samples indicated that all samples had polycrystalline behavior and largely corresponded to stage Hg-1223.. The critical zero temperature of substituted Hg-1223 compounds is 95 to 120 K. The highest value of critical zero temperature (120 K) was found in $HgBa_{1.7}Y_{0.3}$ $Ca_2Cu_3O_{8+\delta}$ compound. The increasing of yttrium Substitutions produce different data indicated that all samples had polycrystalline behavior and largely corresponded to the high phase (H-1223). Different XRD data indicated that all samples had polycrystalline behavior and largely corresponded to the Hg-1223 phase.

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