Prepare and study the SrO additive on structural and electrical properties for Hg Ba_{2-x} Sr_x $Ca_2Cu3O_{8+\delta}$ superconductor

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Abstract— **In this paper, we study the replacing of Ba by Sr of for $HgBa_{2-x}Sr_xCa_2Cu3O_{8+\delta}$ cuprate superconductor (x=0,0.1,0.2,0.3). The solid state reaction method will be used for forming samples. The X-ray diffraction analysis showed that prepared samples correspond to Hg-1223 phases with tetragonal structure. To find the critical temperature T_c, the measure electrical resistivity will be used by four-probe technique. It is shown that the T_c increase at addition of the Sr from 113K (x=0) to 138K (x=0.3).**

***Index Terms*— Superconductors, Tetragonal structure, X-ray diffraction, Electrical Resistivity, Critical temperature.**

I. Introduction

It is well known that the Hg-based superconducting cuprates $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ {n=1 to 8, and n is the number of consecutive Cu-layers} represent the most interesting homologues series from high temperature cuprate superconductors. It has the high (T_c) by this series which exhibited [1]. 94K is T_c for $HgBa_2CuO_{4+\delta}$ (when n=1), 127 K is T_c for $HgBa_2CaCu_2O_{6+\delta}$ (when n=2) and T_c = 136 for $HgBa_2Ca_2Cu_3O_{8+\delta}$ (when n=3).The T_c has been further increased up to 150-160 and increased up to 155-163 under high stress[2].

There is system crystallizes with perovskite layers for all phases of the $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ [3]. The structure of Hg-based superconductor is almost the same Tl-base, but there is the importance change in the oxygen vacancies for $Tl\text{-}O_{1-\delta}$ layers very few, while the oxygen atoms in Hg-Oδ layers are weakly [4,5]. The $Cu\text{-}O_2$ planes are present, which are responsible for the high-temperature superconductivity [6].

In this paper, there are important measurements to study the structural (XRD) and electrical (resistivity electrical) properties for samples. The resistivity (ρ) is one of the most important characteristics of material, it is the most common method of determining the Tc of a superconductor.

The present paper has been organized as follows. In section 2 is devoted to present the experimental. In section 3 the result and discussions are illustrated. Finally in section 4 the conclusion is presented.

Materials and method

The compound $HgBa_{2-x}Sr_xCa_2Cu_3O_{8+\delta}$ (x=0,0.1,0.2,0.3) has prepared by utilizing the sensitive balance to appropriate weights for the oxides (HgO,BaO,CaO,CuO,SrO) by using soild state reaction method. Accordingly for these chemical formulas:

HgO + 2CaO+ 3CuO+(2-x) BaO + x SrO → $HgBa_{2-x}Sr_xCa_2Cu_3O_{8+\delta}$

Follow the same steps as in the previous search (which mentioned in the our references) to that completed the samples[7-8]. The crystal structures of the $HgBa_{2-x}Sr_xCa_2Cu_3O_{8+\delta}$ compound described by the XRD, which characterized by the following: Source: Cu Kα , current: 30.0 (mA),voltage: 40.0 (kV), wavelength: 1.5405 2θ range: 10- 80(deg), scan speed: 8(deg/min). The estimation of lattice constants and identification of the superconducting phases by using the program[9]. In order to calculate the volume fraction of the phase the following formula will be used [10] :

$$V_{ph} = \frac{\sum I_O}{\sum I_O + \sum I_1 + \sum I_2 + \sum I_{other\ (peaks)}} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots(1)$$

We found the densities (d_m) by using following equation [11].

$$d_m = W_m / N_A V \quad \ldots\ldots\ldots\ldots\ldots(2)$$

where, N_A is the Avogadro's number, the w_m is the molecular weight and V is the volume of unit cell.

The resistivity measurement is given as a function of temperature by using the four-point probe technique at temperature range (77-300K). The value of ρ is found by using the relation:

$$\rho = \frac{V}{I}\frac{\mu t}{L} \quad \ldots\ldots\ldots\ldots..(3)$$

Where, V is the voltage, I is the current, ω is the width, *t* is the thickness and L is the length.

II. Results and discussion

The intensities of the XRD patterns as a function of 2Θ for the pure sample reflections (HgBa2Ca2Cu3O8+δ, x=0) shown in figure (1a), while the relative intensities of the $HgBa_{2-x}Sr_xCa_2Cu_3O_{8+\delta}$ system with x= 0.1, 0.2 and 0.3 are shown in figure 1b-d. It can be seen from this figure the Sr addition produces change in the high and low phases. Table (1) shows decrease in the c lattice parameters, the reason is due to the substitution of Sr for Ba where the ionic radii of Ba [r Ba^{+2}(1.35 A^0)] is longer than that of Sr [r Sr^{+2}(1.12 A^0)] this leads to the expansion at base the structure HgO which leads to decrease in the length of c parameter.

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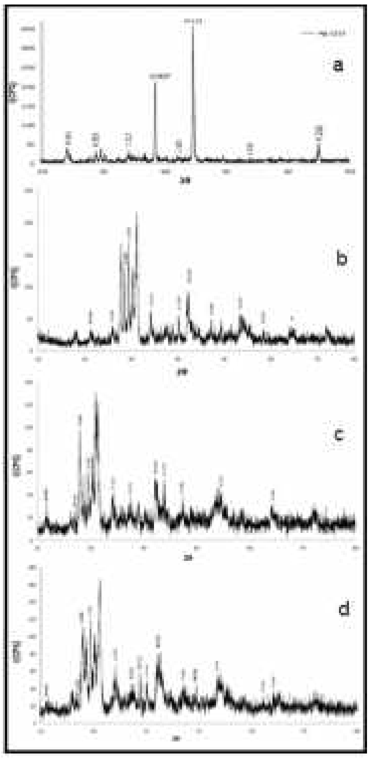
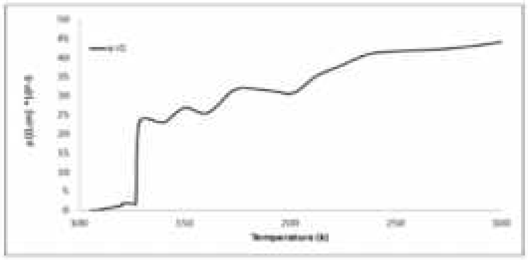
Fig.(2) shows the electrical resistivity versus temperature for pure $HgBa_2Ca_2Cu_3O_{8+\delta}$ compound, where the critical temperature are determined from this figure [12].The resistivity at first drop of the curve $T_{c(onset)}$ (is temperature at which then begins the transition from normal state to superconductor state) of superconductivity is observed at 130 K and the critical temperature at zero-resistivity $T_{c(offset)}$ is observed at 113 K. The change in the transition width (ΔT=17), when strontium oxide (SrO) addition in Barium site of $HgBa_{2-x}Sr_x Ca_2Cu_3O_{8+\delta}$ specimens (x =0.1, 0.2, 0.3) are shown in figure (3). It is worth to mention that all the curves exhibit a transition from normal state to the superconducting state. the critical temperature at zero-resistivity $Tc_{(offset)}$ for $HgBa_{1.9}Sr_{0.1} Ca_2Cu_3O_{8+\delta}$, $HgBa_{1.8}Sr_{0.2} Ca_2Cu_3O_{8+\delta}$and $HgBa_{1.7}Sr_{0.3} Ca_2Cu_3O_{8+\delta}$are 129,128 and 138 K, and $T_{c(onset)}$ are 135,130 and140 K and (ΔT=6, 2 and 2), respectively. The highest of the Tc(offset) was 138 K for $HgBa_{1.7}Sr_{0.3} Ca_2Cu_3O_{8+\delta}$, where shown an increase of the transition temperature with increase of the concentration of strontium Sr, therefore, the volume fraction increasing and the mass density d_M decreasing with increasing Sr concentration as shown in the table(1).

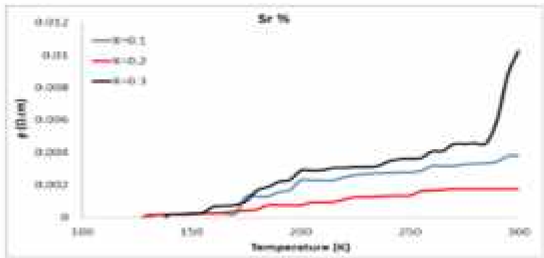


Fig(1). X– Ray diffraction pattern of $HgBa_{2-x}Sr_xCa_2Cu_3O_{8+\delta}$ system with x= 0.0, 0.1,0.2 and 0.3



Fig(2) Temperature dependence of resistivity for $HgBa_2Ca_2Cu_3 O_{8+\delta}$

X	$T_{c(OFF)}$ (K)	$T_{c(ON)}$ (K)	a(A^0)	b(A^0)	c(A^0)	c/a	d_M (g/cm^3)	$V_{Ph-1223}$
0.0	113	130	3.842	3.842	15.75	4.09942	1.533	69.43
0.1	129	135	3.832	3.832	15.3510	4.00602	1.527	71.45%
0.2	128	130	3.8456	3.8456	15.3811	3.99966	1.503	77.932 %
0.3	138	140	3.392	3.392	15.4431	4.5528	1.48	82.111 %



Fig(3) Temperature dependence of resistivity for $HgBa_{2-x}Sr_xCa_2Cu_3 O_{8+\delta}$

Table 1

III. CONCLUSIONS

In the present paper, we have successfully synthesized the HgBa2-xSrxCa2Cu3O8+δ high-Tc superconducting compounds with x=0.0, 0.1,0.2 and 0.3. We have investigated the effect of simultaneous doping of Sr at Ba site of Ba-O2 layer in $HgBa_2Ca_2Cu_3O_{8+\delta}$ with special emphasis on correlation between superconducting properties and the observed microstructural features. The XRD data showed that samples correspond to Hg-1223 phase. The critical transition temperature $T_{c(0ffset)}$ of the Sr doped Hg-1223 compounds range between 113 to 138K. The highest Tc value 138K has been found for $HgBa_{1.7}Sr_{0.3}$ $Ca_2Cu_3O_{8+\delta}$ compound. Substitutions of Sr produce change in lattice parameter, volume fraction and mass density .

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