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Partial substitution Effect of Pb and Mg on the Structural and Electrical Properties of High Temperature ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCu_4O_{10+\delta}$) Superconductor

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ABSTRACT

Superconductor samples with chemical composition ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCu\ O_{10+\delta}$) were prepared by solid state reaction method. The effect of partial substitution of Pb and Mg on the structural and electrical properties of this compound were studied. The lattice parameters were characterized by using X-ray diffraction technique and the results showed that all the samples crystallize in tetragonal crystal structure. This technique proved increase in value of lattice constant (c) with increasing in Pb concentration until 0.4 when y= 0 and decreased after this concentration. On the other hand the partial substitution of Mg in Ca showed decreasing in the value of (c) with increasing Mg concentration to (0.2,0.4,0.8,1,1.4,1.6) when the Pb is constant at (0.4), but the value of (c) increased with increasing Mg to (0.6,1.2). Standard four-probe method used in electrical resistivity measurements and the measurements showed an improvement in Tc from (0.1-0.4) and after this concentration Tc value decreased at substitution of Pb in Hg when Mg=0, where the critical temperature increases from 121K to 134K with an increase of x from 0 to 0.4 and decreases after this concentration to 120K , but for substitution of Mg in Ca the Tc is increased to 135K,136K,139K,142K and 145K with increasing of Mg to (0.2,0.4,0.8,1,1.4) and decreased to 134K,140K and 140K with increasing concentration of Mg to (0.6,1.2,1.6) while Pb is constant at (0.4). The surface has been investigated by using scanning electron microscope (SEM) and atomic force microscopy (AFM). These tests were shown that all specimens which tested have good crystalline and homogeneous surface .

Introduction

Superconductors with a critical temperature higher than 77 K that discovered in 1987 by Wu et. al [1], It was called high-temperature cuprate superconductors, cuprates superconductors have attracted the interest of researchers since its discovery, boosted by both their unexpected physical properties and possible technological applications, allowed by their high critical temperature (Tc). One of the most important high-temperature superconductors is mercury-based superconductors, because they have high critical temperature of 133 K to 164 K measured at ambient and high pressure of 30 GPa [2,3].

In 1933 by Putilin et al [4], the first member of the series $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ [Hg-12(n-1)n] Was found , which has a critical temperature equal to 94 K and the structural formula $HgBa_2CuO_{4+\delta}$. Then (Schilling et al.) [2] reached to a critical temperature equal to (133K) in the Hg-Ba-Ca-CuO system, after that they reported about the formation of the two systems Hg1212 and Hg-1223 phases depending on the mercury base $HgBa_2Ca_{n-1}Cu_nO2_{n+2+\delta}$ series, Hg-1201, Hg-1212, Hg-1223 and Hg-1234 phases have been discovered .The first member of the series Hg-1201 when n=1 has tetragonal crystal and highest Tc up to 95 K and lattice constant equal a=3.876 Å and c equal to 9.515 Å [5], all systems have a tetragonal structure but they differ at their critical temperature and lattice constant as follows, Hg-1212 a=3.8552 Å c=12.6651 Å and Tc=(124-≤128) K [6,7], Hg-1223 a=3.852 Å c= 15.83 Å and Tc=135K

[8], Hg-1234 a=(3.8540-3.858) Å c=(19.006-19.011) Å and has Tc up to 125 K [9][10]. The crystal structure of the mercury cuprate superconductor and Tl-Ba-Ca-Cu-O cuprate superconductor are similar, where Hg instead of Tl [4]. It has a multiple number of perovskite structure producing a tetragonal structure. This multiple is depending on the number of Cu-layer inserted in the mixture ($HgBa_2Ca_{n-1}CunO_{2n+2+\delta}$) .

Lamia Khdhair Abbas [11] studied the effect of Ag and In doping on the Tc and structural properties of the Hg_{1-X} $(Ag,In)_X$ Ba_{2-y} $Sr_yCaCu_3O_{8+\delta}$ superconductors, It was found that the critical temperature rises from 116 K to 117.5 K and The length of the C axis is increased from 15.7779 Å to 15.8143 Å with increased concentration of Sr from (0) to (0. 1) and x equal (0), thus found that the best partial substitution ratio for (Sr) in (Ba) is 0.1. Also found that partial substitution of Ag leads to increasing Tc from 117.5 K to 118 K and then to 127 K and the length of the C axis is increased from 15.8143 Å to 15.8519 Å and 15.9238 Å with the increase of the concentration of (Ag) in (Hg) from 0 to 0.1 and 0.2, when y=0.1 and mentioned that the increasing in length of the C axis is due to difference in ionic diameter, where the ionic diameter of (Ag) is greater than the ionic diameter of (Hg). On other hand, concluded that the increasing of the concentration of (In) in the (Hg) from (0) to (0.1) and (0.2) and(0.3) when y = 0.1, leads to decreasing the critical temperature from 117.5 K to 116 and increases to 122 K and then to 125 K , and the length of the C axis decreases from 15.8143 Å to 15.8091 Å and 15.7602 Å and increases to 15.8318 Å and mentioned that the decreased in length of the C axis is due to difference in ionic diameter, where the ionic diameter of (In) is smaller than the ionic diameter of (Hg).

Nawazish A. Khan and Shahid Nawaz [12] studied the effects of doping Mg on the superconducting properties of compound $Cu_{1-x}Tl_xBa_2Ca_{3-y}Mg_yCu_4O_{12-\delta}$ with different concentrations of Mg in Ca and found that the highest critical temperature can be obtained in the compound at y = 1.5 with a zero resistivity critical temperature equal to 131K and an onset of superconductivity are 143 K, but without Mg doping shows the onset of superconductivity at 136 K and zero resistivity at 121 K, but the length of the axis (c) was decreased from 18.126 Å to 18.102 Å and to 18.081 Å for y equal to (y=0,1.5, 2.25), they mentioned that the decrease in length of the C axis is due to difference in ionic diameter, where the ionic diameter for (Mg) is smaller than the ionic diameter of the(Ca) .

Adnan Younis and Shama Seher [13] studied The response of $Cu_{0.5}(Tl_{0.5-y}Hg_y)Ba_2Ca_3Cu_2Zn_2O_{12-\delta}$ (y=0,0.15,0.25 and 0.35) superconductors in electric and magnetic fields and they found that the effect of partial substitution of mercury in thallium for this compound leads to a decrease in the value of the C axis from 18.084 Å to 17.892 Å when increasing the concentration of (Hg) from (y=0) to (y=0.25). but they found increase in the zero resistivity critical temperature from 105K to 108K and 113K when the concentration changes from (y=0) to (0.15) and (0.25).

Noor S. Abed and Sabah J. Fathi [14] studied the Effect of Partial substitution of Ag on the Structural and Electrical Properties of High Temperature $HgBa_2Ca_2Cu_3O_{8+\delta}$ Superconductor. It was found that The highest Tc in compound $Hg_{1-x}Ag_xBa_2Ca_2Cu_3O_{8+\delta}$ equal to 144 K at x=0.3 and this compound has a tetragonal polycrystalline structure with high ratio of Hg-1223 phase.

Bilal A. Omar and Sabah J. Fathi [15] studied the Effect of Zn on the structural and electrical properties of high temperature $HgBa_2Ca_2Cu_3O_{8+\delta}$ superconductor They found that the samples had a crystalline structure of type tetragonal before and after partial substitution of Zn in Ca, and they found that the best concentration of Zn in Ca was 0.05 where the temperature were raised from 120 K to 132 K.

The main objective of this research is to reach the highest critical temperature in Hg-1234 by investigating the effect of partial substitution of lead in mercury and magnesium in calcium in Hg-1234 .

Experimental

The samples (Hg_{1-x} $Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) at (x=0.1,0.2,0.3,0.4 and 0.5),(y=0) and (y=0.2,0.4,0.6,0.8,1,1.2,1.4 and 1.6),(x=0.4) were prepared by solid state reaction method from a mixture of HgO,PbO,BaO,CaO,MgO and CuO, (purity 99.99 %) (England/GCC). The weight of stoichiometric amounts of these powders were measured using a sensitive balance, after weighting the powders were mixed together and ground by using agate mortar ,during the process of grinding, we add sufficient quantity of iso-propanol to get homogenization mixture, process of grinding continue about (50-60) minute .The mixture was dried in an (oven) at (50-60) °C about 1h to remove the added iso - propanol solution, after this pressed in to disc shaped pellets 1.3 cm in diameter (0.3) cm thick by hydraulic press, under pressure of 7 ton/cm^2. The pellets were sintered by a programmer furnace at 850 °C for 24 h with a rate of 5 °C/min and cooled to room temperature by the same rate of heating this process was performed using oxygen, figure (1-A) shows that sintering process. In the second step the samples annealing as shown in figure (1-B) ,where the pellets are grind and then pressed by the same way as before and it is placed in the furnace and raise the temperature from room temperature to 600 °C with a rate of heating 5 °C/min and remain at this temperature about 12h , and then the furnace heat is raised to 850 °C with a rate of heating 5 °C/min and remain at this temperature about 24 h then cooled to temperature of 600 °C by the same rate of heating and remain at this temperature about 12 h then cooled to

room temperature by same rate of heating, this process was performed using oxygen.

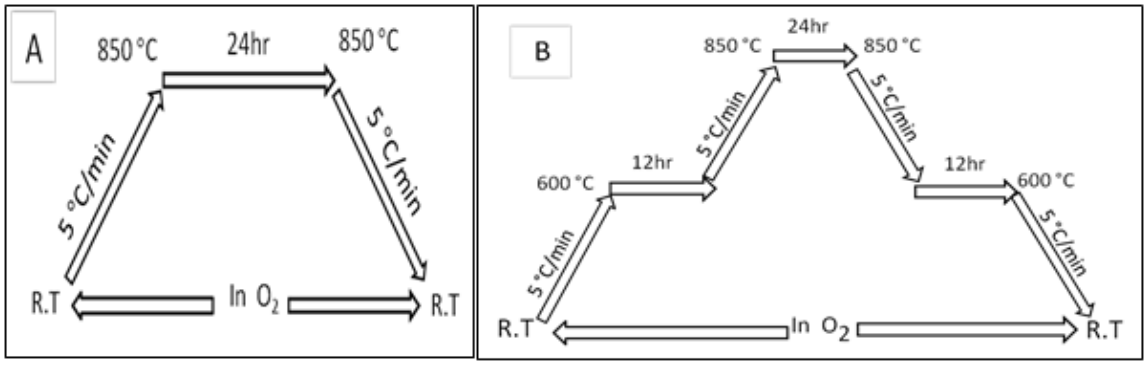

figure (1) A- sintering process, B- annealing process

The prepared samples were characterized by X-ray diffraction technique , type shimadzo with a Cu k_α source of wavelength (1.54 Å) and 40 KV voltage ,and current 30 mA . The relative volume fraction of any phase was calculated from the following relation [14] :

$$V_{ph} = \frac{\Sigma I_o}{\Sigma I_o + \Sigma I_1 + \Sigma I_2 + \Sigma I_n} * 100\ \% \ldots\ldots\ldots\ldots (1)$$

Where I_o is represented the XRD peak intensity of the phase which was determined , and $I_1, I_2, \ldots I_n$ are represented the peaks intensity of all XRD .

Four probe dc methods were used to measure the resistivity (ρ) and to determine the critical temperature (Tc). The Critical temperature is find according to the following relation [15] :

$$\rho = \frac{(R * A)}{L} \ldots\ldots (2)$$

Where R represents electrical resistance and A represents area of specimens, L is length of specimens. The iodometric titration method used to calculate oxygen content[16]. To ascertain the ratio of elements in the compound, the EDX technique was used, which is one of the important techniques by which to obtain information about the elements that form the compound .

Results and discussion

The crystal structure of the prepared samples ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) when (x=0.1,0.2,0.3,0.4,0.5) (y=0) and (x=0.4), (y=0.2,0.4,0.6,0.8,1,1.2,1.4,1.6) were studied from X-ray diffraction as shown in fig (2,3). It could be seen from the result of XRD patterns spectra that the two main phases in all samples of this compound by partial substitution of Pb and Mg in this system, this phases are high-Tc phase Hg-1234 and low –Tc phase Hg-1212 and a small amount of impurity phases. The letters H and L with miller indices in figures of X-Ray diffraction indicate to high-Tc phase Hg-1234 and low–Tc phase Hg-1212 sequentially. The results showed that all the samples crystallize in tetragonal crystal structure.

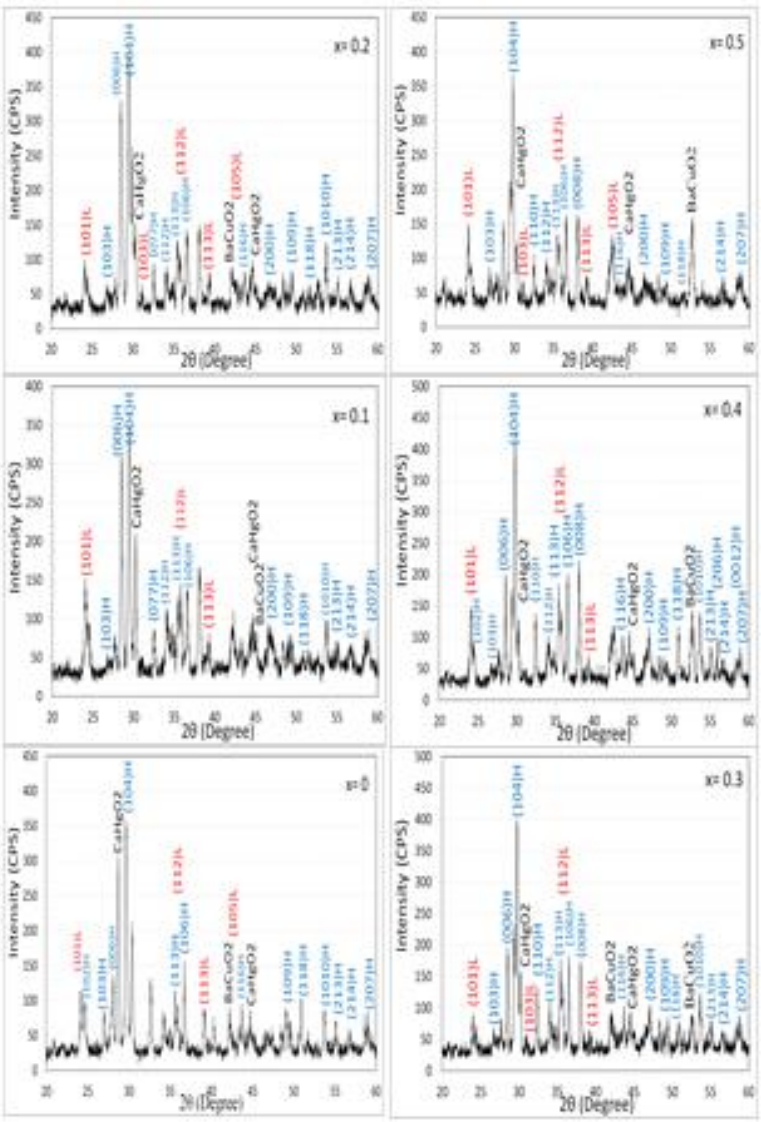

Fig (2) XRD for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) when X= (0,0.1,0.2,0.3,0.4,0.5) ,y=0

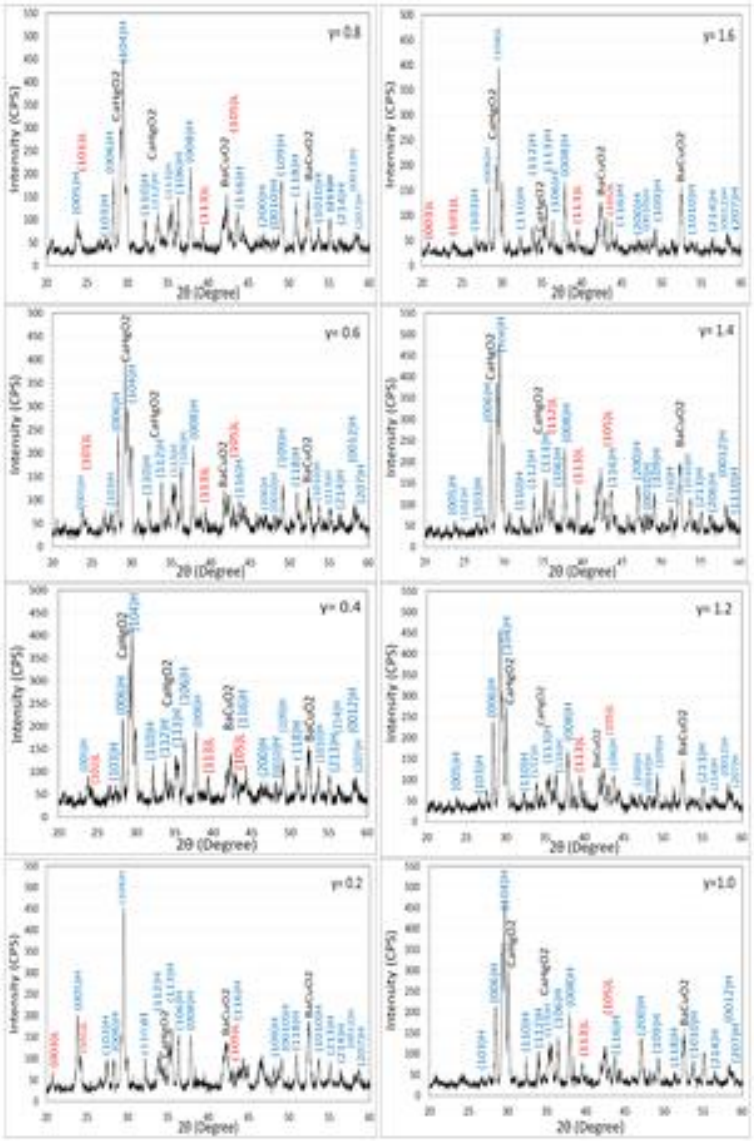

Fig (3) XRD for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) when y =(0.2,0.4,0.6,0.8,1, 1.2,1.4.1.6) , X= 0.4

The presence of pb and Mg in the structure of the Hg-1234 system by Partial substitution of Pb in Hg and Mg in Ca have a direct influence on the increasing of the high Tc – phase (Hg-1234). Where we note the increase of the high Tc – phase and value of c lattice constant and (c/a) and size of cell for Pb doped from (0 - 0.4) and decrease after this concentration when y= 0, as shown in table (1), This results show that a good agreement by same behavior with [17]. Through (c/a) the shape of cell can be identified and in any direction there is increase or growth in the shape of cell. The increase in (c/a) promotes the tetragonal phase of cell , and this mean that there is increase in length of (z-axis) in ratio to length of (x,y) axis. The change in length of (z-axis), has an important role in determining electrical properties, where thought the change in direction of (z) effects the layers of CuO_2 that present on length of this axis, which have a role in determining electrical properties of superconductors. The table (1,2) shows that increase in high-Tc phase (Hg-1234) with the increase in value of (c/a), when partial substitution of Pb and Mg in compound.

Table (1): variation in Lattice parameters, unit cell volumes, c/a and volume fraction high-Tc Phase Hg-1234 for $Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$ samples with x concentration when y=0.

x	a (Å)	c (Å)	V ($Å^3$)	c/a	V-ph (1234)
0	3.8541	19.0490	282.955	4.9425	78.10
0.1	3.8555	19.0584	283.301	4.9432	78.95
0.2	3.8562	19.0803	283.729	4.9480	80.05
0.3	3.8566	19.0857	283.869	4.9488	80.59
0.4	3.8572	19.1166	284.417	4.9561	82.00
0.5	3.8562	19.0123	282.718	4.9303	74.77

such results may be due to the difference between the ionic radius for Pb and Hg, where the ionic radii for Pb (1.19 Å) larger than that ionic radius of Hg (1.02 Å) which render c lattice constant to be longer or get deformed. The appearance of more than two phases with some impurities phase like $CaHgO_2$,$BaCuO_2$ could be related to the stacking faults along the c-axis then this leads to deforming the structure this interpretation agrees well with [18]. The deformation of the structure is always considered as the cause of the high conduction in the perovskite multi layer state which give rise to some kind of polarization at enough high Tc. This polarization will let the holes or electrons move long distance without suffering scattering process this interpretation agrees well with [19]. On the other hand, when Ca doped by Mg with concentration (y= 0.2,0.4,0.6,0.8,1,1.2,1.4 and 1.6) and Pb in Hg with constant concentration x= 0.4 for all samples, observed increase in high Tc – phas (Hg-1234) with decreased the value of (c) lattice constant and increase (c/a) size of cell when the concentrations of Mg were equal to (Mg= 0.2,0.4,0.8,1,1.4 and 1.6), this results show that a good agreement by same behavior with [12], such results may also be due to the difference between the ionic radius for both of Mg and Ca, where the ionic radius of Mg (0.72 Å) Smaller than the ionic radius of Ca (0.99 Å). The value of (c) lattice constant decreased by substituting Mg at the Ca sites, which increases the coherence. Moreover, the electronegativity of Mg is larger than that of Ca and the presence of Mg develops better correlation between the CuO planes[12].

Moreover, the value of high Tc – phas decreases with increased value of c - lattice constant and decreased (c/a) size of cell when the concentrations of Mg equal to (y=0.6,1.2) as shown in Table(2).

Table(2): Variation in Lattice parameters , unit cell volumes , c/a and volume fraction high-Tc Phase Hg-1234 for $Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$ samples with y concentration when x constant at 0.4

y	a (Å)	c (Å)	V ($Å^3$)	c/a	V-pb (1234)
0	3.8572	19.1166	284.417	4.9561	82.00
0.2	3.8563	19.1151	284.262	4.9568	82.30
0.4	3.8529	19.1111	283.701	4.9602	82.81
0.6	3.8576	19.1149	284.450	4.9551	81.77
0.8	3.8505	19.1049	283.256	4.9617	83.40
1	3.8481	19.0948	282.753	4.9621	84.26
1.2	3.8544	19.1011	283.774	4.9557	83.05
1.4	3.8431	19.0778	281.768	4.9642	85.24
1.6	3.8429	19.0762	281.715	4.9640	83.47

The contraction and increase in the length of the c axis when doped Mg in Ca and pb in Hg is attributed also to the difference between the ionic radius of both Pb and Mg with the host element Hg and Ca. two added components in the compound at the same time ,the ionic radius of the first Pb larger than the ionic radius of the host material Hg and the ionic radius of second addion Mg Smaller then the ionc radius of the host material Ca, was the cause of increasing the axis of c for some concentrations of mg and its decreases to other concentration [11].

The electrical resistivity of the prepared samples at different concentrations of Pb and Mg for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) is shown in fig (4).

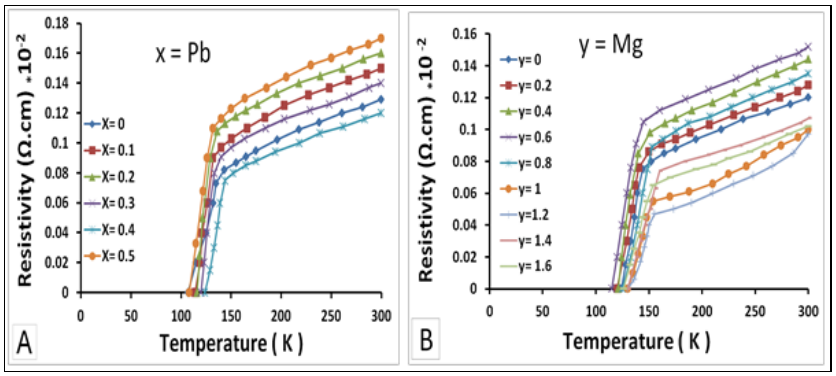

fig (4) Temperature dependence resitivity for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) samples when A: (x=0,0.1,0.2,0.3,0.4,0.5 ;y=0), B:(y=0,0.2,0.4,0.6,0.8,1,1.2,1.4,1.6 ; x=0.4).

From fig (4-A) the critical temperature Tc increases by increasing Pb in Hg from 0 to 0.4 and decreases its value after this concentration when y=0, as shown in the table (3).

On the other hand From fig (4-B) when Ca doped by Mg we found an increased in Tc value for certain concentrations and decreased for other concentrations, when x is constant at 0.4,as shown in the table (4).

The highest critical temperature for pb doping in Hg is equal to (134 K) at x= 0.4,y=0, but for Mg doped in Ca equal to (145 K) at y=1.4 ,x=0.4. The results show that there is a relationship between the (x,y) concentration and critical temperature, high Tc – phase, and the ratio of oxygen content, where the critical temperature increases with the increasing of the high Tc-phas and oxygen content and decreases with decreasing the value of the high Tc-phas and oxygen content as shown in table (3,4), also the length of the c axis according to the added element (x,y) concentration effect on the critical temperature this results show that a good agreement by same behavior with [17]. An arise of δ has been attributed to the existence of excess oxygen atoms in the Cu-O_2 layers. This leads to create more holes in the perovskite layers and shortening in the bond length of the Cu-O and improving the Tc. Thus, any change in the value of x, y will change the value of (c), high-Tc phase Hg-1234 ratio and the ratio of the oxygen content to which the critical temperature depends.

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Table (3) : Variation in Tc values and oxygen content for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) samples with x concentration when y=0 .

X	Tc (K)	δ
0	121	0.192
0.1	123	0.215
0.2	126	0.244
0.3	130	0.289
0.4	134	0.320
0.5	120	0.237

Table (4) : Variation in Tc values and oxygen content for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) samples with y concentration when x constant at 0.4

y	Tc (K)	δ
0	134	0.320
0.2	135	0.335
0.4	136	0.340
0.6	134	0.287
0.8	139	0.373
1	142	0.416
1.2	140	0.393
1.4	145	0.447
1.6	140	0.400

The EDX technique was used to obtain information about the elements that form the compound, figure (5) shows that EDX patterns for compound ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) when (x=0,y=0) (x=0.4,y=0) (x=0.4,y=0.1.4) which represent the pure compound and the compounds that give the highest critical temperature, and shows the emersion of the elements that form the compound. The results of EDX demonstrated that there is not unwanted element in the sample ,this implies that the sample are not contaminated during the synthesis process.

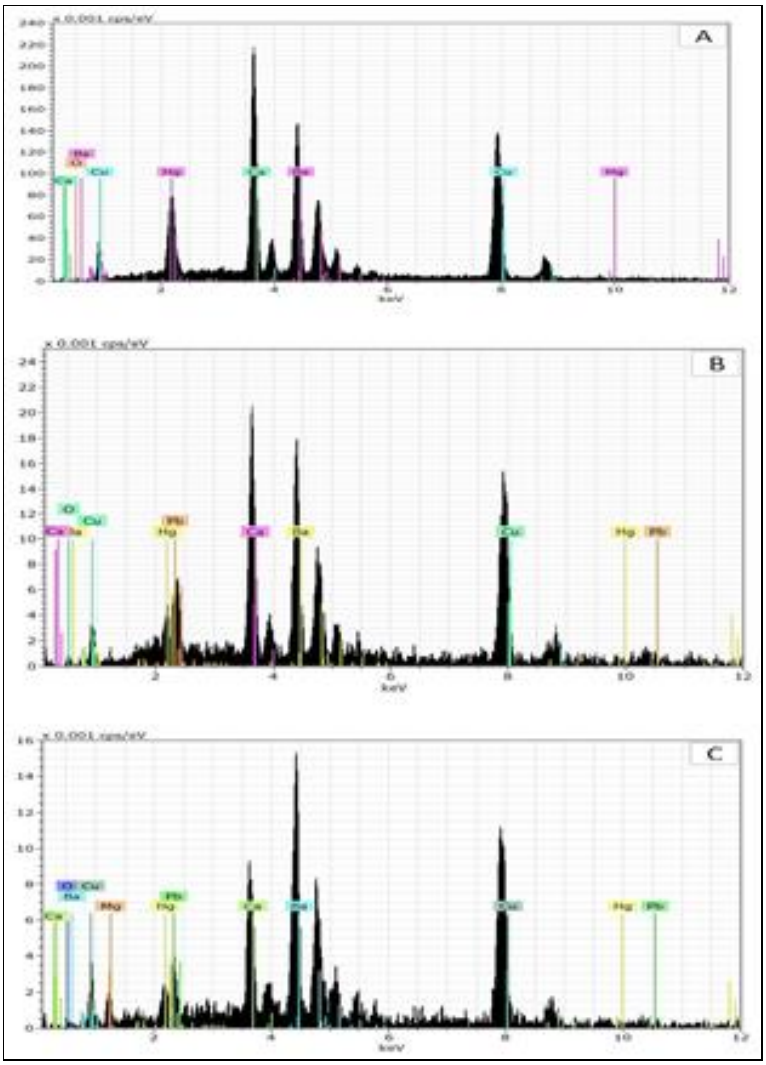

Figure (5) The EDX pattern for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) compound when A- (x = 0 , y = 0) , B- (x = 0.4 , y = 0), C- (x = 0.4 , y = 1.4)

Images of scanning electron microscope for the surface of compound ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) When (x= 0 , y = 0), (x = 0.4, y = 0), (x=0.4, y = 1.4), it was analyzed using the program (Image-J), which works on the analysis of surface images for samples and then calculates grain size, the calculated grain size by using this program were close to that calculated using X-Ray diffraction. It was clear that the convergence in the grain size tend to a good indication for the homogeneity in the crystal structure for all compounds beside the effect of the grinding during the synthesis process. Figure (6) shows that SEM micrographs for compounds (x=0,y=0) (x=0.4,y=0)(x=0.4,y=0.1.4), which represent the pure compound and the compounds that give the highest critical temperature. The dark areas represents Increase the ratio of Heavy elements and light areas represent the ratio of light elements Located in the compound which changes with value (x,y) this interpretation agrees well with [20].

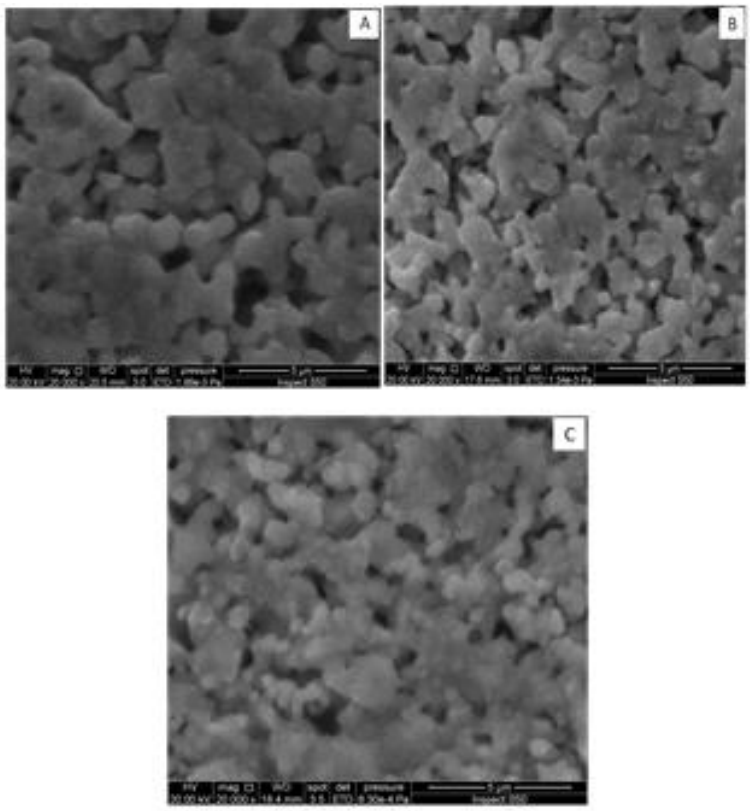

Figure (6); Represent SEM for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) compound when A-(x = 0 , y = 0) , B-(x = 0.4 , y = 0) ,C-(X = 0.4 , y = 1.4)

Atomic force microscopy technique was used to study surface morphology for samples (x=0,y=0),(x=0.4,y=0) (x=0.4,y=1.4) and observed that there are tortuosity, high density areas and low density areas that differed from one location to another. The surface roughness Sa for compounds and root mean square Sq values when (x=0,y=0),(x=0.4,y=0) and (x=0.4,y=1.4) can be observed in the Table (5), the results shows that all specimens which they tested have good crystalline and homogeneous surface. Figure (7) shows that 3-D AFM images of the ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) compounds when (x=0,y=0),(x=0.4,y=0) and (x=0.4,y=1.4).

Table (5): Average surface roughness, root mean square values for ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) that give the highest critical temperature .

($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$)	Sa nm	Sq nm
(x=0,y=0) pure	334.67	505.55
(x=0.4,y=0)	349.24	427.99
(x=0.4,y=1.4)	352.42	448.68

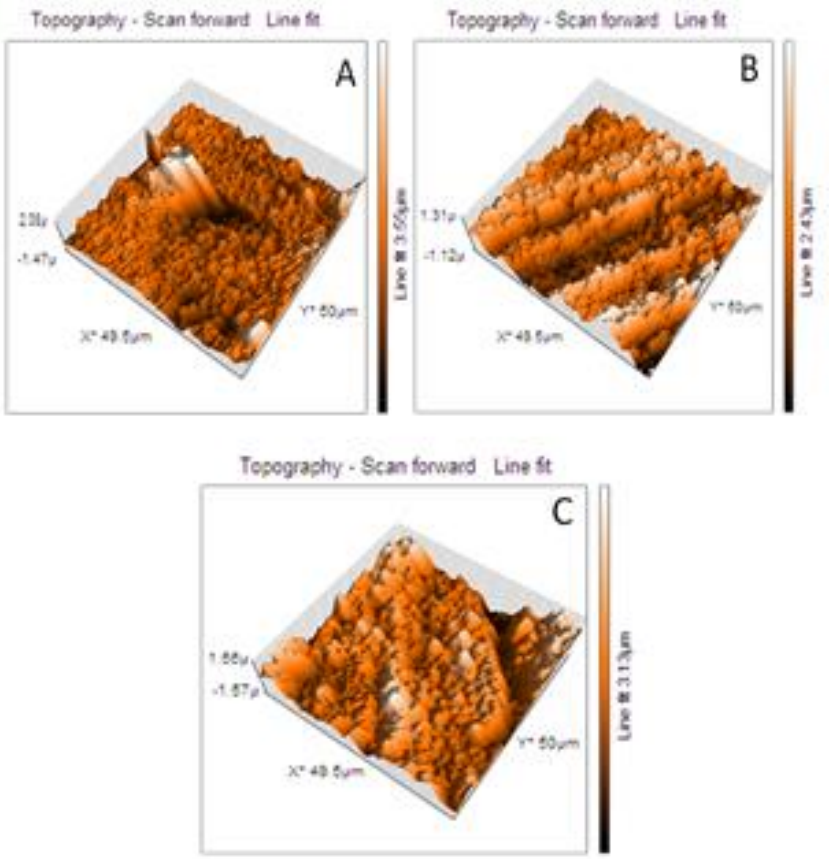

Fig (7) : AFM surface images of ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) compound when A-(x = 0 , y = 0) , B- (x = 0.4 , y = 0) , C- (X = 0.4 , y = 1.4).

Conclusion

For the addition of (Pb) in (Hg), the critical temperature, high Tc-phase H-1234, and length of C-axis increases with the increase the concentration of Pb changes from x=0 to x=0.4 at y=0. However, when (Mg) is added in (Ca) and when the concentration of (Pb) constant at 0.4, the critical temperature and high Tc-phase Hg-234 increase but C-axis length decrease when the concentration of (Mg) equal to y=0.2,0.4,0.8,1,1.4. On the other hand we found that length of C- axis increase but the critical temperature and high phase H-1234 decreased for (Mg) equal to y=0.6, 1.2. The decreased c axis length possibly increases the Fermi-velocity of the carriers along the c axis and increases the critical temperature of the material.

Any deformation of the structure or increase or decrease in the length of the c axis depends on the difference in the ionic radius of the added element and the host element.

The deformation of the structure is always considered as the cause of the high conduction in the perovskite multi layer state which give rise to some kind of polarization at enough high Tc. This polarization will let the holes or electrons move long distance without suffering scattering process.

The highest critical temperature obtained in this ($Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCuO_{10+\delta}$) compound is 134K at (x=0.4,y=0) , and 145K at (x=0.4, y=1.4).

The results of EDX demonstrated that there is not unwanted element in the sample ,this implies that the sample are not contaminated during the synthesis process.

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تأثير التعويض الجزئي بالرصاص Pb والمغنسيوم Mg على الخصائص التركيبية والكهربائية للمركب الفائق التوصيل الكهربائي $(Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCu_4O_{10+\delta})$ عند درجات الحرارة العالية

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الملخص

حضرت نماذج من الموصلات الفائقة وبالتركيب الكيميائي $(Hg_{1-x}Pb_xBa_2Ca_{3-y}Mg_yCu\ O_{10+\delta})$ بطريقة تفاعل الحالة الصلبة. تم دراسة تأثير التعويض الجزئي لكل من Pb و Mg على خصائص المركب التركيبية والكهربائية .ثوابت الشبيكة وصفت باستخدام تقنية حيود الاشعة السينية وأظهرت النتائج ان جميع العينات تتبلور بتركيب بلوري رباعي قائم, اثبتت هذه التقنية ان قيمة ثابت الشبيكة c تزداد مع زيادة تركيز Pb الى 0.4 عندما y=0 , وتنخفض قيمتها بعد هذا التركيز. من ناحية اخرى وعند التعويض الجزئي ب Mg في Ca اظهرت انخفاضا في قيمة c مع زيادة تركيز Mg الى (0.2,0.4,0.8,1,1.4,1.6) عندما تكون Pb ثابتة عند0.4, ولكن ان قيمة c تزداد مع زيادة Mg الى (0.6,1.2). استخدمت طريقة (Standard four-probe) لقياس المقاومية الكهربائية وأظهرت القياسات تحسنا في Tc من (0.4 -0.1) وبعد هذا التركيز لوحظ انخفاض في قيمة Tc وذلك عند التعويض ب Pb في Hg وعندما Mg=0 اذ ازدادت درجة الحرارة الحرجة من 121K الى 134K مع زيادة قيمة x من 0 الى 0.4 وانخفضت بعد هذا التركيز الى 120 K. اما بالنسبة لتعويض Mg في Ca فان Tc تزداد الى , 136K, 139K, 142K, 145K 135K مع زيادة Mg الى (1.4,1,0.8,0.4,0.2) وتنخفض الى 134K , 140K , 140K مع زيادة تركيز Mg الى (0.6,1.2,1.6) عندما Pb ثابت عند 0.4. تم التحقق من السطح باستخدام المجهر الالكتروني الماسح (SEM) ومجهر القوة الذرية (AFM) واظهرت هذه الاختبارات ان جميع العينات التي تم اختبارها متبلور بشكل جيد ولها سطح متجانس.