Effect of Pressure on the Structural and Electrical Characteristic of Hg $Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}$ System

Ibrahim Khaleel Resen
Department of Physics, College of Education (Ibn-Al-Haithem), University of Baghdad, Baghdad, Iraq

Abstract: The high temperature superconductor**Hg $Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}$**compound for different values of pressure (4 and 6 ton/cm^2) was prepared by a solid state reaction method . It has been found that the specimens were superconductorsat p= 4 and 6 tons/cm^2also the transition temperature T_c= 145$c^{\circ}$is the maximum at (p =6 ton/cm^2) for x = 0.6 .X- ray diffraction showed a tetragonal structure with the variation of the lattice constant(c) with increasing of the pressure .

تاثير الضغط على الخواص التركيبية والكهربائية للمركب

فائق التوصيل

ابراهيم خليل رسن

قسم الفيزياء / كلية ابن الهيثم / جامعة بغداد

الخلاصة :

تم تحضير المركب **Hg $Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}$** فائق التوصيل بضغوط مختلفة

(p= 4 , 6 ton/cm^2) بطريقة تفاعل الحالة الصلبة . وقد اظهرت نتائج اختبار العينات انها فائقة التوصيل ضمن درجات الحرارة التي استخدمت هنا , وقد لوحظ ان اعلى درجة حرارة حرجة كانت تساوي ($T_c = K$) عند الضغط (P = ton/cm^2) . واظهرت تحليلات الاشعة السينية ان هذا المركب هو ذو تركيب رباعي (Tetragonal) وبينت هذه التحليلات تغيرا في قيمة ثابت الشبيكة (c) مع زيادة الضغط .

I. INTRODUCTION

High temperature superconductor is a chemical compound including unit cells which represents different elements as a repeating pattern of atoms .There is a critical temperature over the boiling point of nitrogen (77 K) [42] for all types of superconductors which if increasing and approaching from room temperature, the superconductor becomes appropriate for using in a wide applications of live.

The main goal of preparing the compound Hg $Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}$ (1223) is to acheave higher T_c to make it more commonly use in electronic applications and electrical products .

A new era was opened in field of high critical temperature super conductor (HTSC) when both of K.A.Muller and J.G.Bednorz in 1986 [15] apprized superconductivity in LaxBa1-xCuO4 (LBCO) at 30 K then access the imposed degree of 30k that reached by BCS theory .

The research on high T_c superconductor continued on YBa2Cu3O7+δ (for 90k) , then Bi2Sr2Can-1CunO8+x(for 110k) ,and raised at TimBa2Can-1CunO2n+m+2 (125k) and for Hg $Ba_2Ca_{n-1}Cu_nO_{2n+2+x}$ (135k) for normal pressure.

High temperature superconductor oxides have the properties of the superconductor, zero resistivity , flux quantization , meissner effect Josephson effect [43,44,45] in addition of the following characterizations:

(1) Have a structure of highly anisotropic layered.
(2) The HTSC oxides possess a structure of layered crystal .
(3) The HTSC oxides are called "unconventional superconductor" because of the transport properties, pseudo gap, strong anisotropic resistivity, etc .
(4) Specific heat of these oxides is found from the relation: C = $AT^{-2} + \gamma T + \beta T^3$ ……………..(1.1)
(5) The planar in HTSC oxides for the coordination of copper in Cu-O is squared.
(6) The coherencelength (λ) in HTSC is equal to ($\sim 10^{-40}$) $\AA$ while in conventional superconductors is equal to (10^{-4}) cm.
(7) The predicted magnitude of isotope effect by BCS theory which based on electron –phonon interaction is much upper in HTSC oxides.

In HTSC the coherence length (distance between cooper pairs) is about as one or two atomic spacing (from 3∼20$\AA$) and it is shorter in magnitude than of conventional superconductors.

II. EXPERIMENTAL

The specimens were prepared by a solid state reaction. Appropriate amounts of the powder materials $\mathbf{Hg\ Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}}$ were mixed together , the mixture was grinded and regrinded many times to produce a fine powder and then dried in air at 100 °C for one hour . then the powder was regrind again after the mixing of HgO with it and pressed into disc – shaped pellets with different pressure (4 and 6 ton $/cm^2$)

The pellets were sintered in air at 950 °C for 24hwith a rate 50 $°C/h$in afurnace and then cooled to room temperature by the same rate of heating. Four probe dc method at temperature range (77 K) was usedto measure the resistivity (ρ) and to determine the critical temperature (T_c) .

The structure of the prepared samples were obtained by using x-ray defractometer(XRD) type :(Shimaadzu X-ray Diffractometer XRD 6000)) .the lattice parameters for the unit cell could be found from the relation :

$$\frac{1}{d^2} = \frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}$$

Where h,k, l: miller indices .

III. RESULTS AND DISCUSSION

The temperature dependence of the electrical resistivity (ρ) for $\mathbf{Hg\ Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}}$at the pressure (4 and 6 ton/cm^2)are shown in figure (1) it was found that the behavior of the samples was converted to a superconductor at temperature less than the range (125) K .

It was found that the resistivity decreasing with the increasing of the pressure and the superconducting transition were not sharp and had tails around (>300) K. this is may be due to the existence of small amount of the secondary phase 1212or1201.

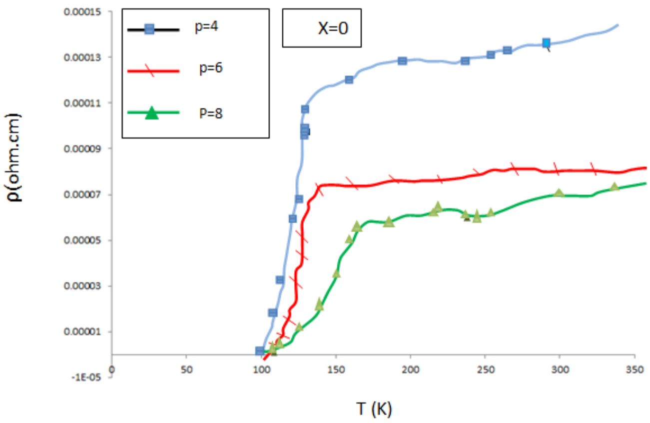

Fig. (1) :temperature dependence of resistivity for $\mathbf{Hg\ Ba_2Ca_{2-x}La_x\ Cu_3O_{10+\delta}}$for various pressure in air .

It is obvious from fig.(2) and table (1) that there is avariation of the transition temperature T_c with increasing pressure . in the range of (p=4 ,6ton/cm^2)there is an increase in the critical temperature , and T_c has a maximum value T_c= 145 K at p=6 ton/$cm^2$for x = 0.6 . After that there is a decreasing in the critical temperature to 120K at p = 6 ton/cm^2 and 4ton/cm^2 . the variation of T_c with increasing of pressure attributed to that , pressure induced change in carrier concentration assuming that the charge distribution among the crystallo graphically in equivalent CuO layers is nonhomogeneous which are agreement with results of MrioRobinowitz [11] .

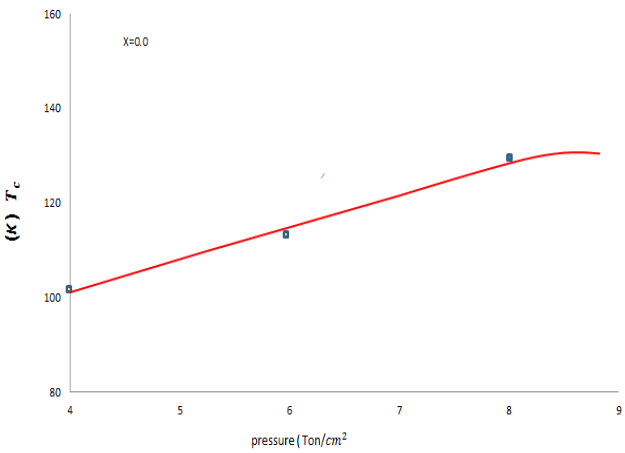

Fig. (2) : critical temperature (T_c) as afunction of pressure .

Table (1) :values of T_c at different pressure.

x	P = 4(ton/cm^2)			P = 6(ton/cm^2)		
	T_{con}(K)	T_{off}(K)	T_c(K)	T_{con}(K)	T_{off}(K)	T_c(K)
0	106	100	103	124	100	112
0.2	118	100	109	140	100	120
0.4	128	100	114	166	100	133
0.6	144	100	122	150	140	145

The crystal structure of the prepared samples were studied by x-ray diffraction (XRD) analysis .X-ray diffraction patterns for all the specimens under study and miller indices exhibitedatetragonal phase as shown in figures (3 , 4 , 5 and 6) with the lattice constants evaluated from 2θ of major peaks at different pressure are also listed in table (2) . the studied samples here exhibited two phases 1223, 1212and the spectra of all samples include some impurity phases such as $CaHgO_2$ and CuO which are agreement with Akao et al. [12],this fact emphasis a polymorphic phase in the structure .

More than two phases is due to the displacement of an ion or oxygen defect or to the ordering of cations which lead to the stacking fauls along the c-axis then this lead to deform the structure.

Table (2) values of the lattice constant, Volume cell and density at differentPressure for Hg $Ba_2Ca_{2-x}La_x$ $Cu_3O_{10+\delta}$system

X	P (ton/cm^2)	a(A°)	b (A°)	C(A°)	c/a	V (A°)^3	ρ_m (g/cm^3)	$V_{ph(1223)}$
0	4	3.841	3.885	15.462	4.025	230.728	0.744	72.5%
	6	3.834	3.887	15.766	4.119	234.956	0.731	73.9%
0.2	4	3.873	3.887	15.770	4.071	237.407	0.910	73.9%
	6	3.846	3.867	15.767	4.099	234.494	0.922	77.3%
0.4	4	3.882	3.888	15.814	4.073	235.252	0.758	77.2%
	6	3.853	3.801	15.827	4.107	231.790	0.769	82.1%
0.6	4	3.901	3.903	15.783	4.045	240.305	0.755	80.2%
	6	3.861	3.769	15.831	4.100	230.374	0.788	85.85%

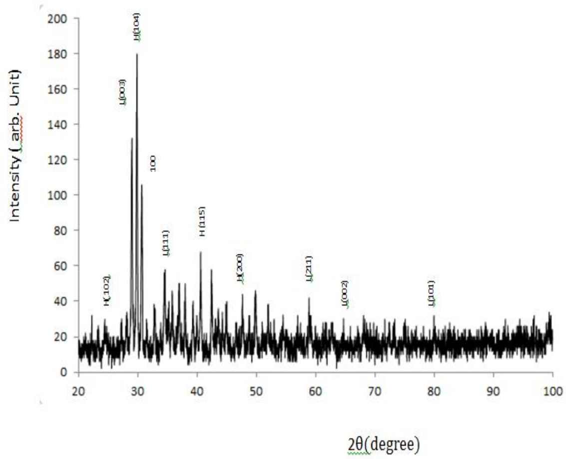

Figure 3: (XRD) pattern of Hg $Ba_2Ca_{2-x}La_x$ $Cu_3O_{10+\delta}$ samples For x=0 and p = 4 ton/cm^2

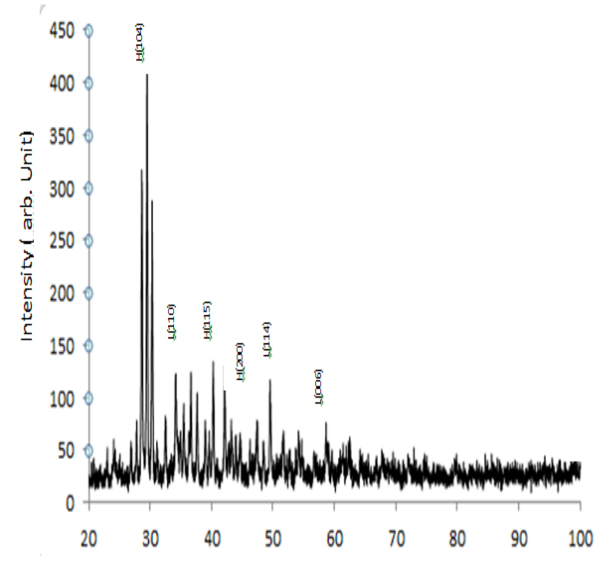

Figure (4) (XRD) pattern of Hg $Ba_2Ca_{2-x}La_x$ $Cu_3O_{10+\delta}$ samples For x=0 and p = 6 ton/cm^2

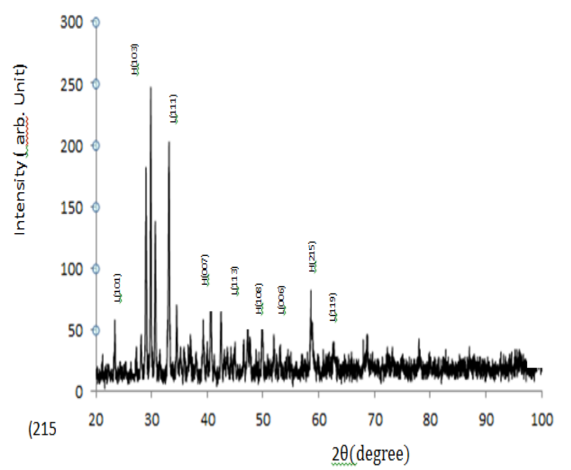

Figure ( ) (XRD) pattern of Hg Ba_2 Ca_{2-x} La_x Cu_3 $O_{10+\delta}$ samples For x=0.2 and p = 4
(b1)

Figure (5) (XRD) pattern of Hg $Ba_2Ca_{2-x}La_x$ $Cu_3O_{10+\delta}$ samples For x=0 and p = 6 ton/cm^2

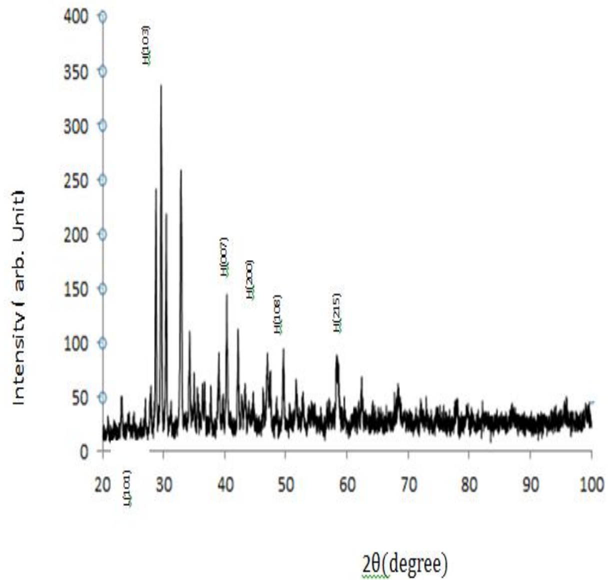

Figure (6) (XRD) pattern of Hg $Ba_2Ca_{2-x}La_x$ $Cu_3O_{10+\delta}$ samples For x=0.2 and p = 6

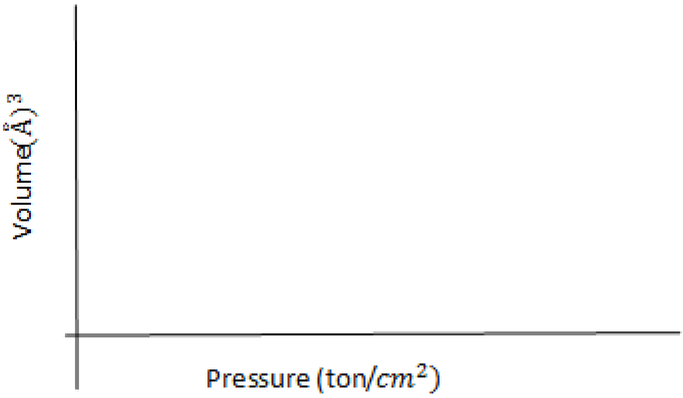

Fig. (7) : variation of volume cell as a function of pressure .

Beside that it was found the values of density for the superconducting sample at different value of pressure from the equation: [13]

$$D = \frac{W_m}{N_A\, V} \quad \text{..................}(1)$$

Where N_A is the Avogadro's number in unit (particles/gm.mol) , V is the volume of unit cell and W_m is the molecular weight in unit (amu).

CONCLUSIONS

1. It can been noticed from the resistivity measurements that :
   a. Behavior of system for all values of pressure is superconductor
   b. Critical temperature increased with the increasing of pressure .the maximum T_c = at pressure p= ton/cm^2 .
2. The X-ray analyses have showed a tetragonal phase .
3. Densities are varies with varying of pressure.

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