

## Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> superconductors Up 99K

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### ABSTRACT

In the present study the effect of replacement of Pb at the Ba place in the oxygen deficient BaO layer of Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> with (0 ≤ x ≤ 0.3) cuprate superconductor has been investigated. Bulk polycrystalline specimens have been prepared by the solid state reaction process. Four probes technique is used to find the T<sub>c</sub>. The highest T<sub>c(offset)</sub> were 88, <77, 97 and 99 K for all specimens with x = 0.0, 0.1, 0.2, and 0.3 respectively. The optimum T<sub>c(off)</sub> of ~ 99 K and T<sub>c(onset)</sub> ~ 106.38K has been found for the composition Ba<sub>1.7</sub>Pb<sub>0.3</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub>. X-ray diffraction analysis showed an orthorhombic arrangement with an increase of the c-axis for the specimens substitution with Pb as compared with those of no Pb content. The change of the Pb content of all specimens created a change in the volume of the unit cell which has an important effect to obtain the superconductor state.

**Keywords:** superconducting transition temperature T<sub>c</sub>, electrical resistivity, Pb content, Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> superconductor

### INTRODUCTION

Superconductor compounds are Multilayered cuprates and generally described by the formula of MCa<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n</sub>, where M refer to Bi<sub>2</sub>Sr<sub>2</sub>[1], Bi<sub>2</sub>Ba<sub>2</sub>[2], HgSr<sub>2</sub>[3], HgBa<sub>2</sub>[4,5], TlBa[6]. The general formula for the Superconducting series of Ba-based is given with the following equation Ba<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n+2</sub>[Ba- 02(n-1)n], where n is the number of CuO<sub>2</sub> layers, this compound consists of a mixture of Ba<sub>2</sub>Ca<sub>1</sub>Cu<sub>2</sub>O<sub>6</sub> (0212), Ba<sub>2</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8</sub> (0223) phases, Ba<sub>2</sub>Ca<sub>3</sub>Cu<sub>4</sub>O<sub>10</sub>(0234) phases and Ba<sub>2</sub>Ca<sub>4</sub>Cu<sub>5</sub>O<sub>12</sub>(0245) phases. These systems exhibit superconductive transition temperatures T<sub>c</sub> of 90 - 120-105 K and 90 K, respectively [7]. It found that the transition temperature (T<sub>c</sub>) to the Ba<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n+2</sub> compound do not depend on the number n of Cu-O planes, with increasing n from 5 to 9, but on the high pressure where temperature T<sub>c</sub> reached to about 80 K [8]. Also the superconductivity was found in apical fluorine system of Ba<sub>2</sub>CaCu<sub>2</sub>O<sub>6-y</sub>F<sub>y</sub>. The highest T<sub>c</sub> of about 108 K has been achieved for the synthesized specimen from a nominal composition of Ba<sub>2</sub>CaCu<sub>2</sub>O<sub>4.4</sub>F<sub>1.6</sub> under high pressure with different (F) [9] "contents. SKOBA, et al" [10], "deposited of superconducting films Ba<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n</sub> (O,F)<sub>2</sub> on a SrTiO<sub>3</sub>(100) substrate by using Nd-YAG pulsed laser ablation under an O<sub>2</sub> pressure of 16-19 Pa. The films exhibited a superconducting onset temperature (T<sub>c(onset)</sub>) of 76.5 K and a zero resistance temperature (T<sub>c(offset)</sub>) of 22.5 K" [10]. In this research fabrication of Ba based [02(n-1)n], n=3 superconductors of nominal composition Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>y</sub> has been investigated and study the structural and resistance measurements in the temperature range 77K.

### Experimental

Purity oxide powders of (BaO, PbO, CaO and CuO) were used as starting materials. The calculated weight depends on molecular weights of these Oxides. The synthesis of specimens have been performed by solid state reaction method, the powders were mixed together by using vortex mixer with grinding time of about 12hrs. Then the powders were pressed into disc shape of (25 mm in diameter and 5 mm thickness) using hydraulic press under a pressure of (100MPa) to insure a uniform transmission of pressure during compact and high density. The specimens

were heated using carbolite furnace at 860 °C for 24 hours with heating rate 5 °C/min, and then cooled to the room temperature by the same rate. The X-ray diffraction technique was used to determine the crystal structure analysis of the prepared specimens of Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> with (0≤x≤0.3) by X-ray diffraction and a computer program ( Full Prof Suite toolbar) was used to calculate the lattice parameters [11] and the density of the specimens (d<sub>m</sub>) were calculated [12]. "The volume fraction of any phase (V<sub>phase</sub>) in the specimen was determined by using the relation"[13]:

$$V_{ph} = \frac{\sum I_o}{\sum I_o + \sum I_1 + \sum I_2 + \dots + \sum I_n} \times 100\%$$

"Where I<sub>o</sub> is the XRD peak intensity of the phase which were determined, I<sub>1</sub>, I<sub>2</sub>, ... I<sub>n</sub> are the peaks intensity of all XRD"[13]. A four-point probe is the most common method to determine the T<sub>c</sub> of a superconductor.

### Rustles and Discussion

According to result of the (XRD) data the structures of all specimens are orthorhombic. From the results in the Table (1), It was found that the lattice parameters (a, b and c) are controlled by Pb content with the change of electrons into anti bonding orbital. "The lattice parameters have been estimated by using d-values and (hkl) reflections of the observed X-ray diffraction pattern through the software program based on Full prof Suite toolbar"[11]. The comparison between of XRD patterns of the (Pb) doped specimens with the relative intensities of the same reflection of the specimen with x = 0.0 (Pb)." The change of the lattice parameters effects on the unit cell volume and causes variation of the density d<sub>m</sub>, which calculated by equation"[14]:

$$d_m = W_m / N_A V \quad [14]$$

"Where N<sub>A</sub> is the Avogadro's number in unit (particles/g.mol), V is the volume of unit cell and W<sub>m</sub> is the molecular weight in unit (amu)"[14]. Figure (2) shown the Variation density with Pb content for the Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> specimens. The increasing of the density d<sub>m</sub> could be attributed to the reduction of the porosity and vacancies in the system. Also from the same table it can be observed that there is an increase in the lattice parameters ratios ( c/a of unit cell) for specimens by increasing the lead concentration as shown in Figure (3), while the volume unit cell (V) decreased for specimens with the increasing lead content except (0.3 wt % Pb) may be due to (pb) substitution instead of (Ba) sites. From the ( ρ – T ) curves which shown in Figure (4). The transition temperature of the specimens was found to be sensitive to the (Pb) the concentrations, it has been observed that the optimum T<sub>c(off)</sub> ~ 99 K and T<sub>c(onset)</sub> ~ 106.38 K for the composition Ba<sub>1.7</sub>Pb<sub>0.3</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> where the (Pb) concentration equal to 0.3 as shown in table 1. "The observed behavior may be attributed to the lead content (Pb) which controls the hole concentrations in conducting CuO planes" [14, 15]. "Thus, induced additions may be change an oxygen contents as expected, which might bring changes in carrier concentration causes the observed values of T<sub>c</sub>"[14], or the increase of substitution(Pb) which leads to increase the holes in the structures thus enhanced the transition temperature from 88K to 99K and reduced the transition width ΔT, they mean that the increasing multiphase Ba-0212(low phase) and Ba-0223(high phase) as clear in Table (2), but at the addition x=0.1, the specimen shows similar behavior and may be having low T<sub>c</sub>, because it behaves like a superconductor, but does not become zero even at the boiling point of liquid nitrogen 77K.

### CONCLUSIONS

In this research the effect of replace of Pb by the Ba place in the oxygen BaO<sub>δ</sub> layer of Bulk polycrystalline specimens Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> with (0≤x≤0.3) cuprate superconductor have been prepared under optimum conditions. X-ray diffraction analysis showed an orthorhombic construction with an increase of the c-axis for the specimens doped with Pb as compare with those have no Pb concentration. It was found that the change of the lead (Pb) content of all

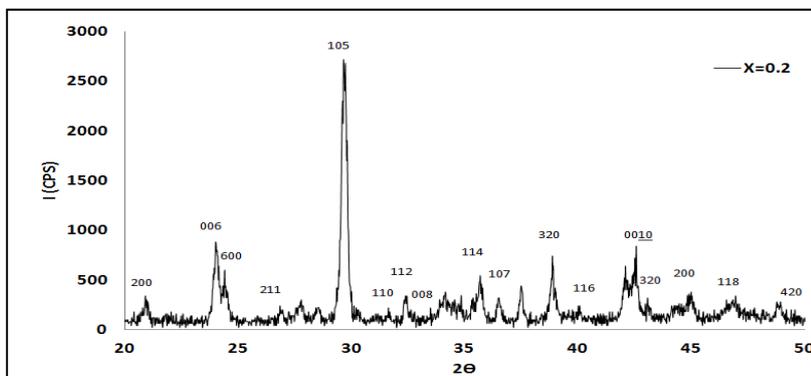
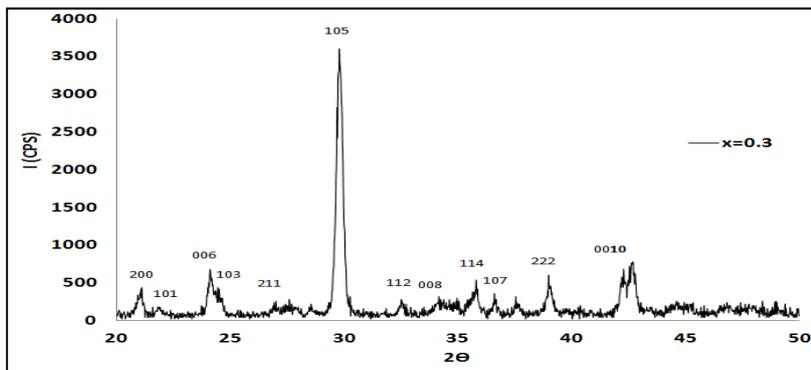
specimens give a change in the volume of unite cell. The transition temperature of as grown specimens is found to be sensitive to the Pb concentrations, the optimum T<sub>c(off)</sub> of ~ 99 K and T<sub>c(onset)</sub> ~ 106.38 K for Ba<sub>1.7</sub>Pb<sub>0.3</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub>.

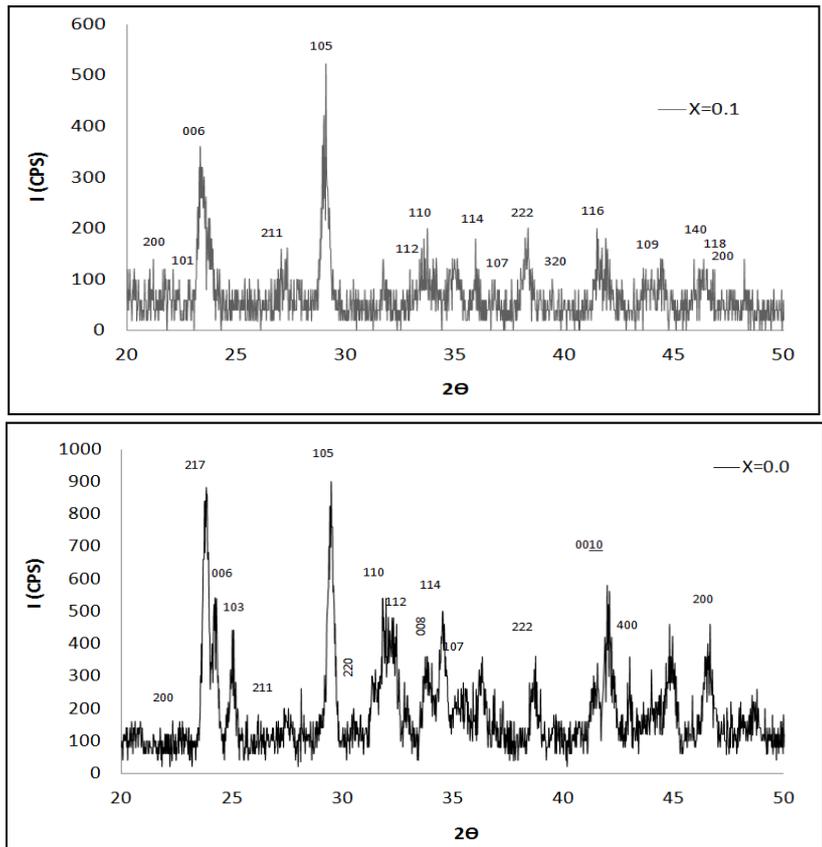
**Table(1): Lattice parameters (a,b, c) , ratio c/a, density (dm), transition width ΔT and volume fraction ( V<sub>ph</sub> ) for theBa<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> specimens.**

X	a ( Å )	b (Å)	c (Å)	c/a	V(Å) <sup>3</sup>	d <sub>m</sub> (g/cm <sup>3</sup> )	V <sub>ph</sub> (High)%	V <sub>ph</sub> (Low)%
0.0	4.25461	4.05369	21.60619	5.078297	372.639	1.76433	75.86	24.14
0.1	8.57678	7.25054	22.07298	2.573573	1372.63	0.48406	83.76	16.24
0.2	4.05288	4.05467	21.59905	5.329299	354.940	1.8916	84.70	15.29
0.3	4.09046	4,09540	23.02507	5.628966	385.717	1.7588	86.16	22.29

**Table(2): T<sub>c(off)</sub> (k) , T<sub>c(on)</sub> (k), transition width ΔT and volume fraction( V<sub>ph</sub> ) for theBa<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> specimens.**

specimens	T <sub>c(off)</sub> (k)	T <sub>c(on)</sub> (k)	ΔT	E <sub>g</sub> (ev)
Ba <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8+δ</sub>	88	97.38	9.38	0.026793
Ba <sub>1.9</sub> Pb <sub>0.1</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8+δ</sub>	<77	<77	-	-
Ba <sub>1.8</sub> Pb <sub>0.2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8+δ</sub>	97	104.9	7.9	0.029533
Ba <sub>1.7</sub> Pb <sub>0.3</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8+δ</sub>	99	106.38	7.38	0.030142





Figures (1) (XRD) pattern for Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>x</sub> specimens for x=0.0, 0.1, 0.2 and 0.3 .

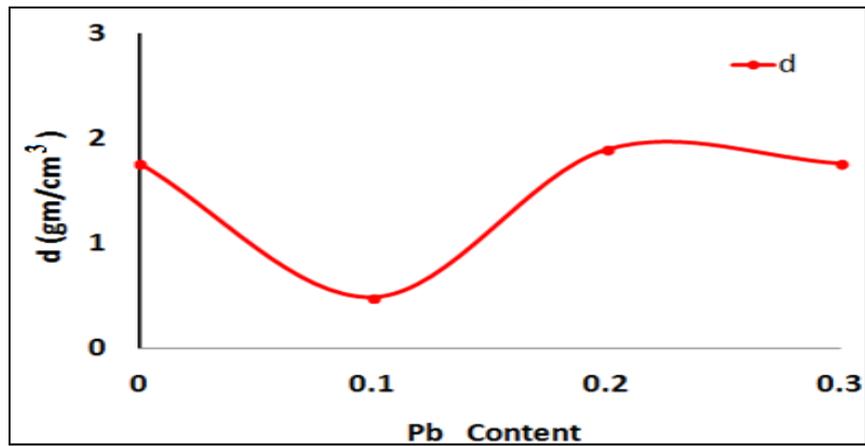


Figure (2 ) Variation density with Pb content for the Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> specimens.

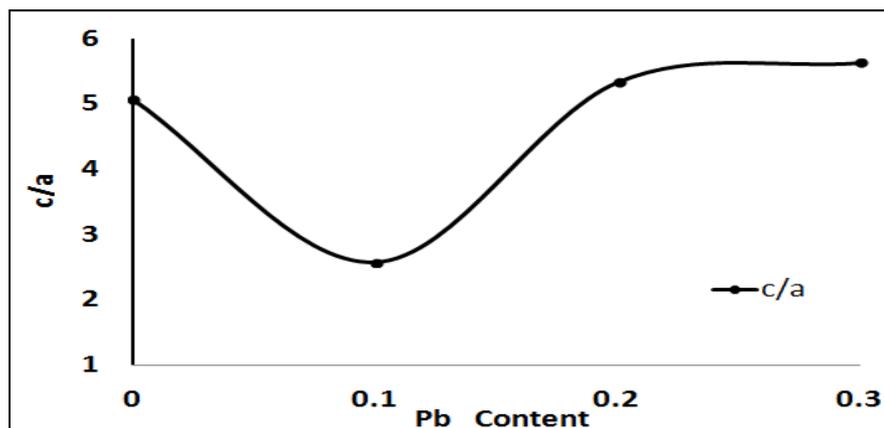


Figure (3) Variation ratio of lattice parameters  $c/a$  with Pb content for the Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> specimens.

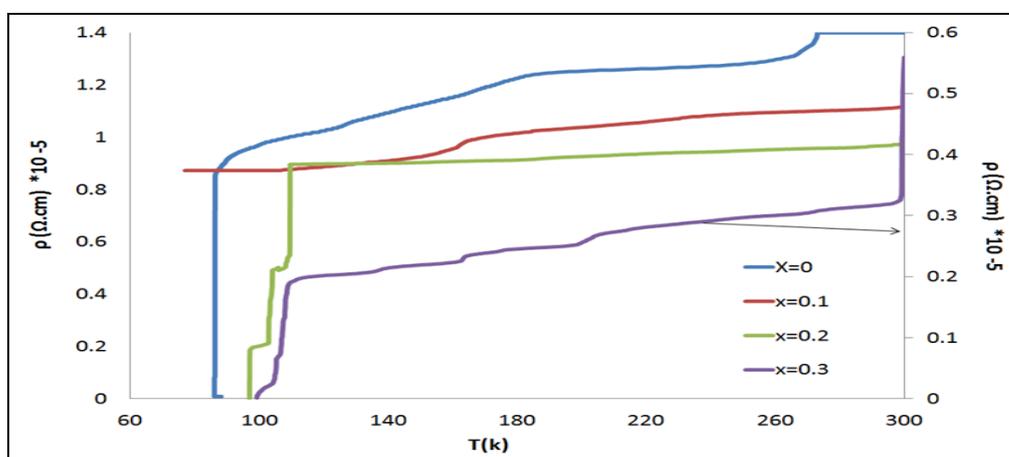


Figure (4) The resistivity as function of temperature for Ba<sub>2-x</sub>Pb<sub>x</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> specimens for  $x=0.0, 0.10, 0.20$  and  $0.30$ .

## REFERENCES

- [1] Khaliq A. Chaudhary, M. Arshad Choudhry;" Preparation and Anisotropic Elastic Property of Bi-Sr-Ca-Cu-O Whiskers" , Turk J Phys 26 (2002) , 61 – 65. c TUBiTAK
- [2] Kareem A. Jasim, Tariq A. Al-Dhahir and Shatha H. Mahdi;" Preparation and electrical, mechanical properties of Bi<sub>2</sub>Ba<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n+4+δ</sub> (n = 1, 2, 3) superconductors " , IJST, Vol. 9, No.3, September 2014. pp65-69
- [3] O. Chmaissem, J. D. Jorgensen, K. Yamaura, Z. Hiroi, M. Takano, J. Shimoyama, and K. Kishio;" Crystal structures of Hg-Sr-Ca-Cu-O superconductors with enhanced flux pinning: Hg<sub>1-x</sub>Re<sub>x</sub>Sr<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n+2+δ</sub>(n=2, 3; x≈0.2–0.25), Phys. Rev. B 53, 14647 – Published 1 June 1996
- [4]Putilin, S. N; Antipov,E.V;Chmaissem,O; Marezio, M. "Superconductivity at 94K inHgBa<sub>2</sub>CuO<sub>4+δ</sub>". Nature **362** (6417):226. Bibcode:1993Natur.362..226P. doi:10.1038/362226a0 (1993).

- [5] L. Gao, Z.J. Huang, R.L. Meng, J.G. Lin, F. Chen, L. Beauvais, Y.Y. Sun, Y.Y. Xue, C.W. Chu; " Study of superconductivity in the Hg-Ba-Ca-Cu-O system", Elsevier ( Physica C: Superconductivity), Volume 213, Issues 3–4, 15 August 1993, Pages 261–265.
- [6] M.P. Siegal, D.L. Overmyer, E.L. Venturini, R.R. Padilla, and P.N. Provencio; " Stability of Tl–Ba–Ca–Cu–O superconducting thin films", J. Mater. Res., Vol. 14, No. 12, Dec 1999, pp4482-4488
- [7] Roland Hott, Reinhold Kleiner, Thomas Wolf & Gertrud Zwicknag; " Superconducting Materials–A Topical Overview" To be published in A. Narlikar (Ed.), "Frontiers in Superconducting Materials", Springer Verlag, Berlin, 2004
- [8] A.Iyo, Y. Tanaka, Y. Kodama, H. Kito, K. Tokiwa, T. Watanabe; " Tc dependence on the number of CuO<sub>2</sub> planes in multilayered Ba<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n</sub>(O,F)<sub>2</sub> superconductors" Institute of Physics Publishing Journal of Physics: Conference Series 43 (2006) PP 333–336, doi:10.1088/1742-6596/43/1/083 7th European Conference on Applied Superconductivity.
- [9] P. M. Shirage, D. D. Shivagan, A. Crisan, Y. Tanaka, Y. Kodama, H. Kito and A. Iyo; " Superconductivity at 108 K in the simplest non-toxic double-layer cuprate of Ba<sub>2</sub>CaCu<sub>2</sub>O<sub>4</sub>(O,F)<sub>2</sub>", Journal of Physics: Conference Series 97 (2008) 012163 doi:10.1088/1742-6596/97/1/012163
- [10] S Koba, A Iyo; " Deposition of superconducting Ba<sub>2</sub>Ca<sub>n-1</sub>Cu<sub>n</sub>O<sub>2n</sub>(O,F)<sub>2</sub> thin films by pulsed laser ablation", Journal of Physics: Conference Series 568 (2014) 022023 doi:10.1088/PP1742-6596/568/2/022023.
- [11] An Introduction to the Program Fullprof (2000).
- [12] Shatha Hashim Mahdi; " Synthesis and study structural, electrical and mechanical properties of composite superconductor", Thesis, University of Baghdad, (2015).
- [13] Kareem Ali JASSIM; " Structure and electrical properties of lanthanum doped Bi<sub>2</sub>Sr<sub>2</sub>Ca<sub>2-x</sub>La<sub>x</sub>Cu<sub>3</sub>O<sub>10+δ</sub> superconductor", Turk J Phys 36 (2012) ,PP 245 – 251. © TÜBİTAK doi:10.3906/fiz-1105-12 .
- [14] Kareem Ali Jasim, Muhammad Abdul-nabi Thejeel, Adil Mahmoud *Ibraheim*; "Preparation and Study the Effect of Cadmium Substitution on the Electrical and Structural Properties of Bi<sub>2</sub>Sr<sub>2</sub>Ca<sub>2-x</sub>Cd<sub>x</sub>Cu<sub>3</sub>O<sub>10+δ</sub> Superconductor ", International Review of Physics (IREPHY), Vol 8, No5, (2014)
- [15] Kareem A. Jasim; "Superconducting properties of Hg<sub>0.8</sub>Cu<sub>0.15</sub>Sb<sub>0.05</sub> Ba<sub>2</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>8+δ</sub> ceramic with controlling sintering conditions ", J Supercond Nov Magn. Springer. DOI 10.1007/s10948-012-1507-3, PP1713-1717