International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Superconducting Properties of $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ System

L.K. Abbas† and W.M. Abdullah†*

†Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq

Accepted 15 Jan 2016, Available online 26 Jan 2016, **Vol.6, No.1 (Feb 2016)**

Abstract

High temperature superconductors with a nominal composition $Bi_{1.7-x}Pb_{0.3}AS_xSr_2Ca_2Cu_3O_{10+\delta}$ for x=0, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4 and 0.5 was prepared by solid state reaction method by two steps. The effect of substitution of As on Bi sites, sintering time and sintering temperature has been investigated. The results showed that the optimum sintering temperature is equal to 830ºC and sintering time is 140 h. Substitution of As will increase the transition temperature. The highest T_c obtained for $Bi_{1.7-x}Pb_{0.3}AS_xSr_2Ca_2Cu_3O_{10+\delta}$ composition was 125K⁰ for the sample with x=0.25. The x-ray diffraction analysis showed an orthorhombic structure with a high Tc phases (2223) as a dominant phase and low Tc phase (2212) in addition to some impurity phases. Lattice parameter values of prepared samples have been calculated.

Keywords: *$Bi_{1.7-x}Pb_{0.3}AS_xSr_2Ca_2Cu_3O_{10+\delta}$ superconductivity; critical temperature; X-ray diffraction.*

1. Introduction

Since Maeda *et al* (H. Maeda *et al*, 1988) discovered superconductivity in the BSCCO system, significant research has been focused on the synthesis and the use of various dopants to volume fraction high T_c phase in multiphase ceramics. This family of superconductors can be expressed by the general formula $Bi_2Sr_2Ca_{n-1}Cu_nO_{2n+4}$, where (n=1, 2, 3), n is CuO layers(P. Agarwala *et al*,1999). Dependence on n values, the three phases have different critical temperature, the Bi-2201 has 10K, the Bi-2212 has 80K, and the Bi-2223 has 110K.

The formation and stability of the high- T_c phase can be modified with many methods by the addition or substitution of element of varying ionic radii and bonding characteristics. Many studies of doping into superconductor oxide ceramics have been made in order to improve their properties.

Among these, addition or partial substitution of trivalent Bi with Pb has been found to be the most effective method (S. A. Sunshine *et al*, 1988). It found that lead atoms act as efficient nucleation and growth sites for the formation of the Bi-2223 and enhance the diffusion of the calcium and copper atoms (D. Shi *et al*,1989). Sb has been stated to be effective in preventing Pb from evaporating during calcinations in BPSCCO system (K. Kocaba·s,1998). Substitution of Pr^{+3} and Ce^{+4} at Ca^{+2} sites in BiPb-2212 superconductor cause decrease the T_c value (V. P.S. Awana *et al*, 1993). Substitution of Ce and Pr at Ca sites in the BiPb-2223 superconductor not only leads to a Tc depression but also to the formation of BiPb-2212 phase (R . R . Kothawale *et al*, 2002; R. Sinbh *et al*, 1998]. The substitution of divalent Ca by rare earth ions, e.g., Y^{+3}, Gd^{+3} in the BiPb-2223 system reduces the amount of holelike carriers and leads to force a metal-insulator transition (MIT) above a critical concentration (C. Quitmann *et al*, 1992; F.S.Ahmed, 2015). Addition of Eu to BiPb-2223 superconductor helped in improving the formation of the high phase, while the critical temperature T_c decreases with increasing of Eu content(S.A.Halim *et al*, 2010).

In this paper we investigated the effect of substitution As on Bi in $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ for $0 \le x \le 0.5$ on the structural and superconducting properties.

2. Experimental

The samples under study prepared by conventional solid-state reaction. Bi_2O_3(99.9%), Pb_3O_4(99.9%), $Sr(NO_2)_3$(99.9%), CaO(99.9%), CuO (99.9%) and AsO (99.9%)powders were used as starting materials. The powders with the molar ratio of [Bi] : [Pb] : [Sr] : [Ca] : [Cu] : [As] = 1.7-x : 0.3 : 2 : 2 :3 : ($0 \le x \le 0.5$) .The powder of precursor was mixed together by using agate mortar. The mixture homogenization takes place by adding a sufficient quantity of 2-propanol to form a past during the process of grinding from about (1 h). In the second step , the materials were grounded to a fine powder and then calcined in air at 800 ºC for (24)h and after the mixture was then pressed into pellets (1.3 cm) in diameter and (0.2) cm thick, using hydraulic

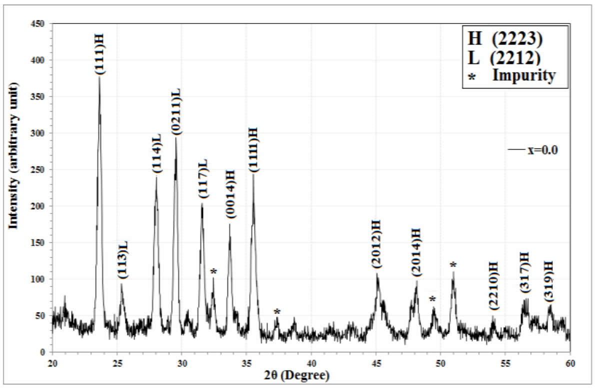
*Corresponding author: **W.M. Abdullah**

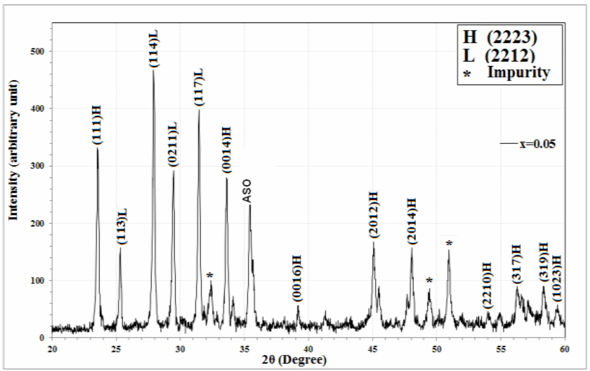
type (SPECAC), under pressure of (5 ton). The pellets were sintered in air at 850 ºC, 835 ºC for (140 h). The structure of the prepared samples obtained by using x-ray diffraction (XRD) type (Philips) with the CuKα source .A computer program has been used to calculate the lattice parameters, which is based on Cohen's least square method (F. Ferguson *et al*, 1984).

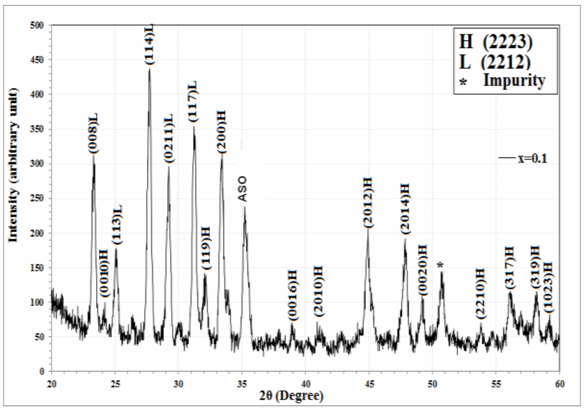
3. Results and discussion

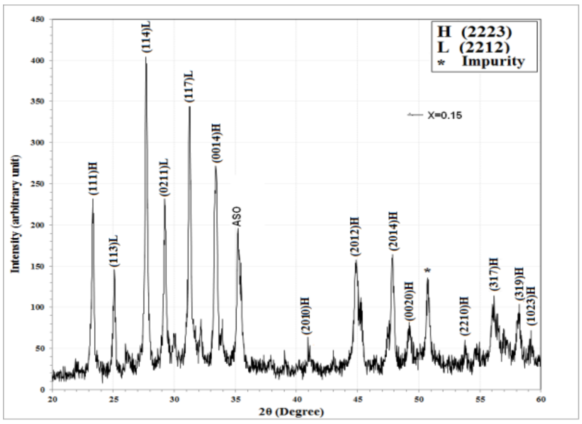
The result showed that the optimum preparing composition with high Tc superconducting behavior is held at 830 ºC for 140h, and the process is carried out in air. The XRD measurement were carried out of all the samples and most of them showed two main phases, i.e., high- T_c phase (2223), low- T_c phase (2212) which include some unidentified impurities. From XRD pattern, it was found that BIPb-2223 has an orthorhombic structure. Fig. (1) shows the XRD patterns for the nominal composition $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ with x= 0,0.05, 0.1,0.15, 0.2, 0.25, 0.3, 0.4 and 0.5. From this figure we can see that the high-T_c phase is the dominant phase. We can see also that the peak intensity of peaks corresponding to 2223-phase decreases with increasing the value of arsenic content to x = 0.1 that leads to decrease the Tc values. At beginning the As content up to x=0.1work on increases the resistance, and depression of the superconducting critical temperature Tc in addition to phase transformation from Bi-2223 to Bi-2212. Increasing of As up to x=0.25 caused to enhance the superconducting high Tc-phase of the compound, where the Tc values start becoming increasingly. More addition of As content (x>0.3) leads to the emergence of another peaks, which is corresponded to some unknown impurity and the crystallinity becomes less, which may be attributed to the substitution of As may be cause more cuprate vacancies that the HTS need, which act a high scattering effect of supper electrons in crystalline structure. From the above mentioned result, we can say thatb the compound is sensitive to As content on the existence of HTP, i.e. when the As content increase the HTP completely destroyed. This case indicates the decreasing of the crystalline arrangement degree, which may come from the localization of charge carriers because of the distortion in crystal structure formed by deformation.

From the crystal structure analysis, we have been found that lattice parameters *a*, *b* and *c* are varies with As content as listed in Table (1). It is found from this Table that there is an increase in both of *a* and *c* lattice parameter values with increasing of As content. This change in the lattice parameters affect the volume of the unit cell and then causes an increase in the density. The deformation in the *c*-axis adjusts the amount of charge transfer from Bi-O layer to Cu-O layer sheet will tend to improve the critical temperature. This behavior may be explained attributed to the differences in the ionic radii for both of As+3.5(1.19 ˚A) and Bi+3.5(0.96 ˚A), which results in the c-axis elongation, then heightening of the high-Tc phase which results in the rapid increase of its Tc, as mentioned previously. The change in the c-lattice parameter is related to the distribution of holes between bismuth oxides layers and CuO planes. The doped ions may change the spacing between the CuO layers and thus affect the charge transfer to the CuO layers (G.A.AL-Dahash,1998). From the crystal structure analysis, we vhave been calculated also the *cla* ratio of these samples. The variation of *cla* with As content for $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ is shown in Fig(2), which is plotted with T_c values.









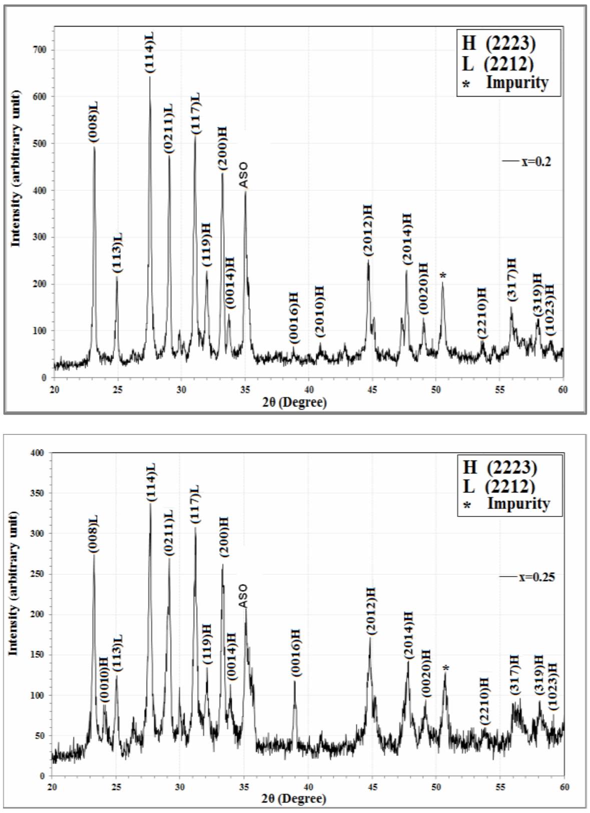


Fig. (1): XRD patterns for the $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ samples with $0 \le x \le 0.25$

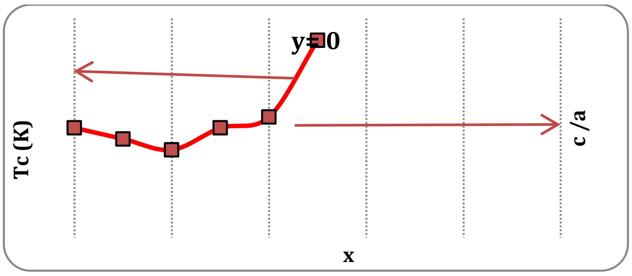


Fig. (2): Transition temperature (T_c), *c/a* ratio and as a function of As content for $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ samples with $0 \le x \le 0.25$.

The temperature dependent of the electrical resistivity of with $0 \le x \le 0.25$ have been studied. The resistivity versus temperature for these samples is shown in Figs.(3 and 4). It is found from Fig(3) the critical temperature of undoped samples is equal to 100K. The sample with x= 0.25 shows a higher critical temperature (Tc=125K), also the compositions with x =0.25, the superconducting transitions are sharp. This result may be attributed to the existence of the high Tc-phase as referred to in the XRD analysis. Increasing As to 0.0,0.05,0.1 caused a decrease the critical temperature, but when increasing As to 0.15,0.2,0.25 caused an increase Tc, the decrease in Tc are further evidence that the presence of the increasing amounts of As content in Bi-2223 phase stabilizes and promotes the growth of Bi-2212 phase at the expense of Bi-2223 (S.A.Halim *et al*, 2010) While that for x=0.3 the compound becomes semiconductor , show superconducting resistance behavior but don't reach to zero resistivity. The reason of that may be ascribed to two effects: (a) The changes of the carrier concentration and microstructure induced by the replacement. (b) The decrease of Tc should be mainly attribute to the magnetic scattering induced by As ions in CuO plane (B.Shu Ahn Bull *et al*,2002).

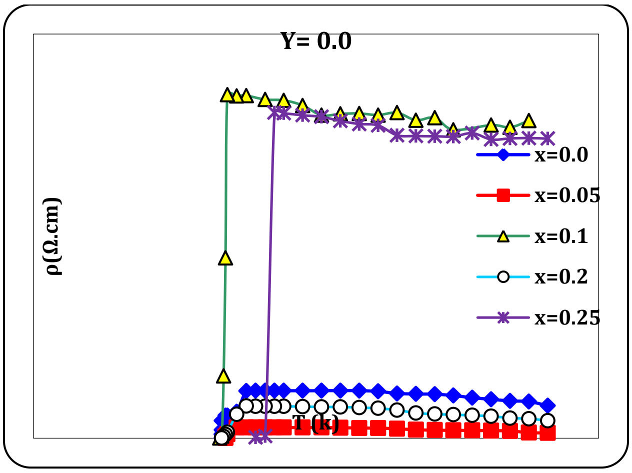


Fig.(3): Temperature dependence of resistivity for $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ samples with x=0.0,0.05,0.1,0.2,0.25

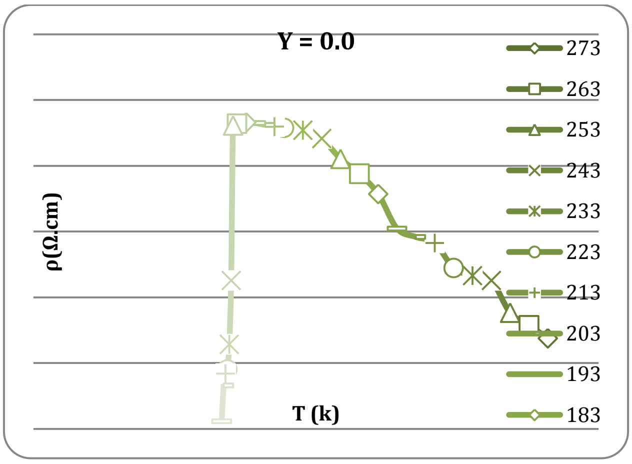


Fig.(4): Temperature dependence of resistivity for for $Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ samples with for x=0.15

Table (1): Variation in lattice parameters, *c/a* and T_c values, for different composition of $(Bi_{1.7-x}Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$ samples with $0 \le x \le 0.25$

x	*a*(Å)	*b*(Å)	*c*(Å)	*c/a*	T_c (K)
0	5.3947	5.4025	37.0365	6.8654	105
0.05	5.4075	5.4132	37.1559	6.8712	102.5
0.1	5.4008	5.3935	37.1283	6.8746	100
0.15	5.4191	5.4232	37.271	6.8777	105
0.2	5.4479	5.4395	37.498	6.8831	107.5
0.25	5.4236	5.5879	37.3709	6.8904	125
0.3	-	-	-	-	sem
0.4	-	-	-	-	=
0.5	-	-	-	-	=

Conclusion

This research presents the experimental results of addition of As in ($Bi_{1.7-x}$ $Pb_{0.3}AS_XSr_2Ca_2Cu_3O_{10+\delta}$) superconductor. The measurements showed that critical temperature was maximum value with x =0.25 where Tc = 125K. XRD patterns analyses show an orthorhombic crystal structure, and there is a increase of c-parameter value with the increase of As content.

References

H. Maeda, Y. Tanaka, M. Fukutomi and T. Asono (1988), A new high –Tc oxside superconductor without a rare earth element , Jpn.J.Appl.Phys Vol.27, P.209.

Priti Agarwala, M.P.Srivastava, P.N.Dheer.V.P.N.Pandmanaban and A.K.Gupat (1999), Enhancement in Tc of Superconducting BPSCCO thick films due to irradiation of energetic argon ions of dense plasma focus, Phys C313, P 87-92.

S. A. Sunshine, T. Siegrist, L. F. Schneemeyer, D. W. Murphy, R. J. Cava, B. Batlogg, R. B. Van Dover, R. M. Fleming, S. H. Glarum ,S.Nakahara,R.Farrow,J.J.Krajewski,S.M.Zahurak,J.V.Waszczak,J.H.Marshall,P.Marsh,L.W.Rupp,Jr.,and W.F.Peek (1988),Structure and Physical Properties of Single Crystals of The 84-k Superconductor $B_{2.2}$ Sr_2 Ca $_{0.8}$ Cu_2 O $_{8+\delta}$ Phys. Rev. B38, P. 893-896.

D. Shi, M. S. Boley, J. G. Chen, M. Xu, K. Vandervoort, Y. X. Liao, A. Zangvil, J. Akujize and C. Segre(1989), Superconducting glass ceramics in Bi-Sr-Ca-Cu-O fabrication and its application ,Appl. Phys. Lett. 55, P. 699.

K. Kocaba·s (1998), Effect of sintering Time on Sb Added BiPbSrCaCuO Superconducting Ceramics ,Turkish Jou of Phys, Vol.22 , P.437- 440.

V. P.S. Awana, S.K. Agarwal, A.V.Narlikar and M. P. Das (1993), Superconductivity in Pr- and Ce-doped Bi2 Ca Sr2Cu2Oy systems ,phys. Rev. B48, 1211.

R . R . Kothawale, B. N. Dole and S. S. Shah :Pramano-J (2002). , The Effect of Substitution of Ce on Superconducting Properties of $Bi_{1.7}$ $pb_{0.3}$ $Sr_2Ca_{2-x}Ce_xCu_3O_{10+\delta}$, phys , Vol . 58, No. 5, P . 871.

R. Sinbh, A. Gupta, S.K. Agarwal, D. P. Singh and A. V. Narlikar (1998), Superconductivity in Pr doped Bi-2223, *Superconductor* SCi.Technol. 11, 311.

C. Quitmann, D. Andrich, C. Jarchow, M. Fleuster, B. Beschoten, G. Guntherrodt, V.V. Moshchalkov, G.Mante, R. Manzke (1992), Scaling behavior at the insulator-metal transition in Bi2Sr2(CazR1−z)Cu2O8+y where *R* is a rare-earth element phys. Rev. B46, 11813.

F.S.Ahmed (2015), Effect of Gd and Ba substitution on the superconducting properties of $Bi_{1.6}Pb_{0.4}$ $Sr_{2-y}Ba_yCa_{2-x}Gd_xCu_3O_{10+\delta}$ compound.

S.A.Halim, S.S.H.Ravandi, M.I.Adam, S.K.Chen and K.P.Lim(2010), Influence of Addition of E_{u2O3} nanoparticle on the structural and Superconducting Properties of $(B_{i1.6}P_{b0.4})S_{r2}C_{a2}C_{u3O10}$ Ceramics, Sci, Technol , Vol. 18, No. 1,P 266.

I.F. Ferguson, A.D. Hardy , M.U.Mod and A. H. Rogerson (1984), A program for the calculation of the intensities of x-ray or neutron powder reflections, part 3phys. Commun., Vol.32, P.83-94.

G.A.AL-Dahash (1998), Effect of Deformation on Electronic Structure and Magnetic properties of Some High Temperature Superconductors.

Beom-Shu Ahn Bull. Korean Chem(2002), Synthesis of BiSrCaCu(Ni)O Ceramics from the Gel Precursors and the Effect of Ni Substitution,Soc: Vol. 23, No. 9.