The Effect of Tungsten Nanoparticles on Superconducting of The Compound $Bi_{2-x}Pb_{0.3}W_XSr_2Ca_2Cu_3O_{10+\delta}$

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Abstract

By using a conventional solid-state reaction technique, a group of the superconducting samples with nominal composition Bi_2-$xPb_{0.3}W_xSr_2Ca_2Cu_3O_{10\pm\delta}$ with ($0 \leq x \leq 0.5$) sintered at 840°C for 140h in the air have been prepared. The effect substitution of tungsten nanoparticles on the physical properties of Bi sites was studied. X-ray diffraction (XRD) studies showed that all our samples are polycrystalline with orthorhombic structures and presence two phases: high-Tc phase (2223), low-Tc phase (2212) and an impurity phase Some impurities like$Sr_2Ca_2Cu_7O_\delta$, CaO and WO . In the prepared samples the lattice parameter values and the volume fraction of high-Tc phase are calculated. Electrical resistivity measurements show that the values of critical temperature Tc increase with tungsten content. The highest transition temperature, T_c, obtained for $Bi_{2-x}Pb_{0.3}W_XSr_2Ca_2Cu_3O_{10+\delta}$ composition was 191.8K with x=0.3.

Keywords: Bi-2223 superconductors; X-ray diffraction; W substitution

I. Introduction

(BiPb)-2223 phases have a great interest among the Bi-based of high-T_c superconductors (HTC) due to the high in transitional temperatures of superconductors. Many studies of substituting into superconductor oxide ceramics are still continuing to develop the superconducting qualities of this phase. The physical properties depend largely on the details of the initial elemental composition and not just on the method of preparation. The reaction of more than one element with each other at high temperatures affects the formation of impurity phases which affect the phase of 2223 to reduction. It was observed that there is an effect of many substituting elements at Ca^{2+} sites in (BiPb)-2223 ceramic on the superconducting properties of bismuth based high-Tc superconductors. The effect of Sn [1], Mn [2], Sm [3] [4], Pr [5], Eu [6] and Gd [7] [8] on superconducting properties were studied. Tungsten has a number of unique properties, these properties include high melting point, high thermal conductivity, and excellent mechanical properties at elevated temperatures. Tungsten has the highest melting point (3683 K) and the best high temperature strength among the common refractory metals. However, tungsten also has several serious deficiencies related to brittleness of the material, including room-temperature brittleness. The use of Nano-crystalline tungsten has been considered one of the approaches that could potentially improve the ductility of tungsten [9]. Therefore, there was diversity in the resistance of ceramics due to the replacement of rare earth elements. They detected that the high-temperature phase gradually changes to the low-temperature phase by increasing of substituting contents. As a result of the replacement of elements in the calcium site in the system (BiPb) -2223 system the conversion of the superconducting to a nonconductor as well as a low T_C with founding of (BiPb) -2212 phase [4] [5]. The value of critical temperature of superconductor oxide ceramics depends on the density of mobile holes in the CuO_2 layers and so on the average Cu valency [10]. The substitution of Ca ions by Gd, Sm and Eu ions leads to a lowering of the formal Cu valence [3, 4, 6, 7, 8], while the replacement of Mn in a Ca site raises the Cu valence [2]. The result the T_c thus rises with increasing Mn contents. Other studies investigated the influence of Ni[10], Zn[12] and Sn[1] on superconducting properties of Bi-Pb-Sr-Ca-Cu-O compound at Cu^{+3} sites. The results appear a weakening of the superconducting characteristics with increasing of these elements content. As well as, many groups have been replaced by Li, As and Sb at Bi^{+3} in the (BiPb)-2223 superconducting phase prepared by solid-state reaction techniques were also studied by Bilgill et al[13] and Abbas et al[14] [15] where they that the volume fraction of (BiPb)-2223 phase was enlargement with increasing of theses element contents. Agil et al. [16] also reported the result of W and Mo substitution together on $(BiPb)_2W_xSr_2Ca_3Cu_{4-y}Mo_yO_{12+\delta}$ system at Bi^{+3} and Cu^{+3}sites respectively. As a result of substitution of (Mo/W) in (Bi Pb) -2223 system leads to lowering T_c slightly. In this study, we will investigate the effect of W substitution on the structural and superconducting properties of bismuth-based compounds.

2. Experimental part

High temperature superconductors with a nominal composition $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+\delta}$ system with ($0\leq x\leq 0.5$), were prepared by a conventional solid-state reaction technique. Solid state reaction technique was used to prepare a homogeneous and well-defined single phase superconducting samples with uniform oxygen stoichiometry for evolution of accurate physical parameters.

The procedure that used to prepare BSCCO system:

1- To prepare samples, take different and suitable weights of high purity materials (99.9%) of Bi_2O_3, PbO, $SrCO_3$, CaO, WO_3 and CuO.

2- To obtain a suitable small size of particles, these materials were crushed and blending together by agate mortar.

3- This mixture was calcined at temperatures from 800°C within 24 hours with a rate of heat 4˚C/min. The mixture obtained is then cooled down to room temperature.

4-The resulting material was compressed at 0.7 GPa as a pellet shape, and the thickness of the material ranges from (2-3) mm, 13mm diameter sintered at 840°C for 140h, with continuous intermediate crushing operations to fulfillment solid-state reactions.

5- X-ray diffraction was analyzed to find out superconducting properties that are carried out on an (Phillips) type diffractometer using $Cu_{k\alpha}$ radiation.

6-A standard DC four-probe technique used to find out superconducting transition temperatures.

3. Results and discussions

Through the XRD analysis of $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+\delta}$ with ($0\leq x\leq 0.5$), it was noticed that the samples have an orthorhombic structure, and also see the appearance of two phases: high-T_c phase (2223) and low-T_c phase (2212). More than two phases may be observed as a result of the stacking faults along the *c*- axis as a result of the movement of an ion or oxygen disorder or to the arrangement of cations. In addition to this, it was observed the presence of some impurities that may be formed during the sintering process. The presence of impurity phases leads to a decrease in the critical temperature (Tc) of the samples.

As shown in (Fig. 1.), when the concentration of tungsten was increased in the samples it affects the improvement of the high-T_c phase (2223). Also, observed that the highest intensity peaks appear at this phase of about 28.8° and 33.4° which correspond to 0012H and 200H, respectively. It was found that the presence of dopant affects the high-T_c phase (2223), so increasing dopant increases its stability. When x = 0.4, the intensity of these peaks begin to decrease and increase the concentration of W adversely effects of the low-T_c phase (2212). It was found that peaks 115L and 117L that appear at 27.4° and 31.2°, respectively, are corresponds to BiPb-2212 phase. It can say that the compound became more sensitive to the content of W, and by increasing the content of W the HTP improved. The results disagree with Agile et al. [16] and Atilla et. .al [17], where they found that a small concentration of W negatively affects the Bi Pb-2223 superconductivity phase.

The lattice constants evaluated from 2θ major peaks, the volume of a primitive unit cell, the volume fraction of high T_c phase and the T_c values are found in Table I. It is revealed that the substitution with Nano W improves the crystallites, increases the intensity of the peaks and sharpens of the peaks, as shown in Fig.1. It also increases in the volume fraction of the high- T_c phase as shown in table I.

The Lattice parameters of high T_c phase BiPb-2223, calculated are presented in Table I. The difference of lattice parameters indicates the interaction of oxygen species. The difference and change in *a*, *b* and *c* parameters values affect the unit cell volume and leads to a change of density. These indicate that Nano W substitution an important to enhance the properties of the superconducting structure samples by decreasing the porosity and impurity phase. This can be attributed to the increased contact area among the superconducting grains. As showed the table I, there is a little increase in the lattice parameter *a*, while there is a larger increase in the lattice parameter *c* with an increase addition of tungsten content.

The temperature-dependent of the electrical resistivity have been studied. The resistivity versus temperature (ρ-T) plots for specimens with nominal composition $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+\delta}$ with $(0 \leq x \leq 0.5)$ is shown in (Fig.2.).

As shown in the figure, substitution of W increases from Tc to Tc=119.8K to x=0.3, due to the increase in the c axis. The natural resistance of pure Bi-2223 samples and samples with low Nano W content shows a superconducting transmission. Containing a concentration of tungsten(x>0.4) the superconductors show a critical temperature below x = 0.3.

Table I appear the variation of T_c(R = 0) values against the W concentration x, for $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+\delta}$ with $(0 \leq x \leq 0.5)$. Note that there is a difference between the transitional temperature values T_c(R = 0) obtained and reported values [14] of the transitional temperatures for samples containing W (BiPb)-2223,where they found that replacing with W leads to a decrease in the transition temperatures but does not prevent the formation of (BiPb)-2223 phase.

In samples without Nano W concentration, the value of Tc is about 113.2 K, while the transmission temperature containing Nano W x = 0.1 is about 114.2K, and finally, the temperature of Nano W x = 0.3 has a degree. 119.8 KB, which is the best value with respect to calculating tc for this compound, but for the samples Nano W x = 0.4 and x = 0.5, we noticed a decrease in Tc compared to x = 0.3. The estimated T_c values increased with increasing W addition. Some studies [16, 17] shown the extent of the effect of replacing Cu with tungsten, it was found that the superconducting transition temperature was depressed by W ion, as it doesn't in our case.

4. Conclusion

The W-doped BiPb-2223 phase was prepared by conventional solid-state reaction technique. The orthopedic structure with a high percentage of the BiPb-2223 superconducting stage, increasing the void, increasing the inter-granular contact space and the impurity phase led to improved superconductivity properties. Also, increasing the temperature of sintering contributes to increasing the critical temperature of Tc. X-ray diffraction (XRD) studies showed that all our samples are polycrystalline with orthorhombic structures.

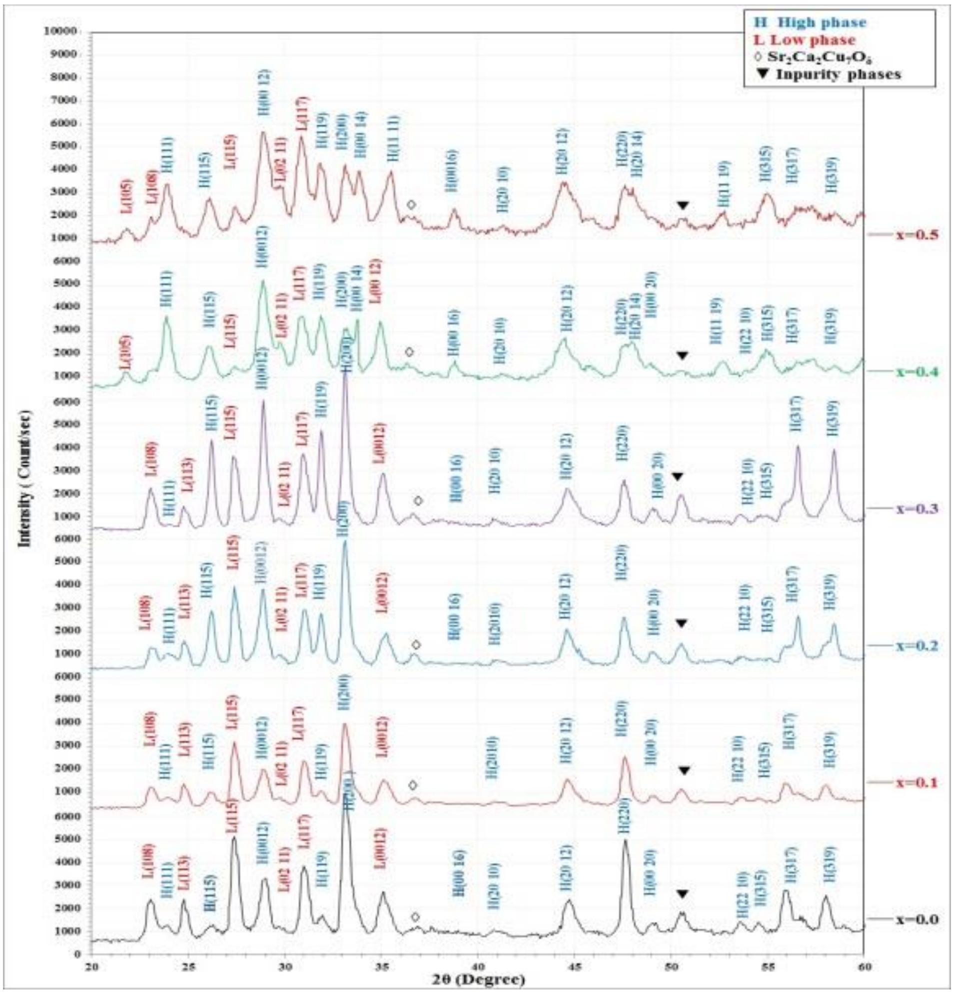

Fig. (1): X-ray diffraction patterns of $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+}\delta$ samples with $(0.0 \leq x \leq 0.5)$ sintered at 840°C for 140h.

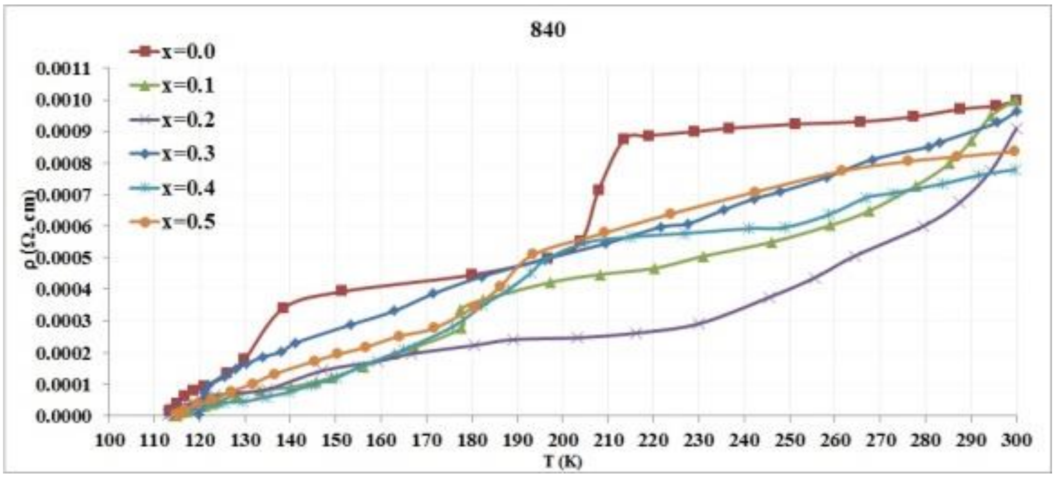

Fig. (2): Resistivity (ρ) as a function of temperature for $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+\delta}$ samples with (0.0≤x≤0.5) sintered at 840°C for 140h.

Table I: Variation in Lattice parameters, unit cells volume, percentage volume fraction of BiPb-2223 phase and critical temperature in $Bi_{2-x}Pb_{0.3}W_xSr_2Ca_2Cu_3O_{10+\delta}$ samples for (0≤x≤0.5).

(W)X	**a(Å)**	b (Å)	c (Å)	V (Å3)	HTP Phase%	Tc (K)
0.0	5.4080	5.3798	36.9849	1076.05	65.65	113.2
0.1	5.4080	5.3921	37.0572	1080.61	64.02	114.2
0.2	5.4080	5.4044	37.0572	1083.08	74.17	113
0.3	5.3989	5.4136	37.1123	1084.69	82.00	119.8
0.4	5.4080	5.4136	37.0572	1084.92	74.72	114.2
0.5	5.4080	5.3798	37.0572	1078.16	76.05	114.8

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