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The Effect of Nd Nanoparticles on (Bi, Pb)-2223 Superconducting

M. M. Abbas[1], Ali Razzaq Abdulridha[2*]
[1]Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq
[2]College of Education for Pure Science, University of Babylon, Hilla, Iraq.
***Corresponding author: E-Mail: ali_rzzq@yahoo.com, Mobile: 009647721500085**

ABSTRACT

The prepared Superconducting samples achieved by a method of solid-state reaction and methodically deliberate for their superconducting properties. Preparation methods of the $Bi_{1.7}Pb_{0.3}Nd_xSr_2Ca_2Cu_3O_{10+\delta}$ compositions with addition of Nd with particle size 50 nm, with (0.1≤x≤0.6) wt %. Studying the Nd nanoparticles effect on the physical properties of superconducting phase. The explored of phase structural characteristics of samples through powder X-ray diffractometer, reveals that all the samples crystallize in orthorhombic structure. Also, phase examination by XRD indicated that Nd nanoparticles enhanced the (Bi, Pb)-2223 phase formation. The method of DC four-probe was used to measure the critical transition temperature (Tc) and found to have maximum value at x=0.2 wt % sample.

KEY WORDS: (Bi, Pb)-2223, Nd nanoparticle, solid state reaction.

1. INTRODUCTION

The most essential innovation of the (Bi, Pb)-2223 superconducting system was achieved by Maeda (1988), meanwhile it has a large chemical resistance against moisture and stable in atmospheric pressure. Hence, numerous researchers study this system. Chen (2004), studied the microstructural and superconductive of BSmCCO with Nd nanoparticles additives were investigated. The Jc was enhanced, especially in high-field regions and in low-field regions by the Nd-BSmCCO samples. The Jc (H, T) and pinning behavior analysis both indicated the action of T_c pinning in the Nd doped samples. The larger active region and the larger enhancement of critical current density of Nd doped samples could be qualified to maximum T_c, the higher solubility of Nd in liquid phase, and the larger size of Nd ions. Aloysius (2005), studied Phase evolution of Nd added (Bi, Pb)-2223 superconductors in bulk form. The Nd concentration of (0.005 ≤ x ≤ 0.030) Bi:Pb:Sr:Ca:Cu = 1.85:0.35:2.0:2.1:3.1. X-ray diffraction investigation displayed the existence of Bi-2212 with the sample. Microstructural investigation exposed that both of morphological and textural matching with a small development of the addition of Nd samples. Similarly Nd replaced at Ca or Sr sites with creation of point imperfections do like flux pinning centers. (Ozkurt, 2007) studied the effects of Nd^{3+} substitution for Pb^{2+} in dilute concentrations of $Bi_{1.7}Pb_{0.3-x}Nd_xSr_2Ca_3Cu_4O_{12+y}$ (x= 0.025, 0.050, 0.075, 0.1) compounds. The results propose increasing in Nd^{3+} doped at Pb^{2+}, where the Bi high phase present in pure sample changes into Bi low phase and hence all samples have a mixed phase formation. Resistivity-temperature results illustrate that there are two steps in T_c; first one happens at 100 K and the other happens from 80 to 90 K, contingent of Nd concentration.

The aim of this research is to inspect the act of addition of Nd nanoparticles on the superconductors chattels of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ samples that prepared by solid-state reaction method.

2. MATERIAL AND METHOD

$Bi1_{.7}Pb_{0.3}Nd_xSr_2Ca_2Cu_3O_{10+\delta}$, bulk samples for (0.1≤ x≤ 0.6) set by solid-state reaction method with appropriate weight for great pureness powders (99.9) % of material Bi_2O_3, PbO, Sr $(NO_3)_2$, CaO, CuO, and nano powder Nd_2O_3 with particle size 50 nm for that proportional to their molecular weight. The powders mixing using agate mortar. A sufficient quantity of 2-propanol was added forming a paste during the process of grinding for about 1 h, to get a homogeneous mixture. Later the combination calcination in air at 800 ◦C for 24 h. Then pressing with disk-shaped pellets 13 mm of diameter, 1–2 mm of width by a manual hydraulic press type (SPECAC) with pressure 0.7 GPa. The pellets sintering at 835ºC. The prepared samples structure was obtained by using X-ray diffraction (XRD) (Philips). The critical temperature (Tc) determination and resistivity measurement achieved by using four-point probe method.

3. RESULTS AND DISCUSSION

The crystal construction of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ with addition of Nd nanoparticles samples sintered at 835 ºC with (0.1≤ x ≤ 0.6) deliberated by XRD and represented in Fig. 1. The results of the X-ray diffraction patterns indicate that all samples had an orthorhombic structure with the existence of both phases; High-T_c phase (Bi-Pb)-2223, which was being the dominant phase, and low- T_c phase (Bi-Pb)-2212, and $Sr_2Ca_2Cu_7O$ as impurity phase of peak at 2θ = 36.8˚ in some samples. Fig. 1 show some reflection lines, such as, H (220) vanished at x=0.6, H (2010) and H (0016) appeared at x= 0.2 and 0.3, while H (111), H (0012) and H (119) decreased at x= 0.6, but L (117) appeared at x=0.6. More over there is unsystematic variation in the growing of Bi-2223 with increasing in the addition of Nd nanoparticles. In addition, no secondary phase observed which includes Nd ions. This shows that the Nd ions go into the crystal construction of (Bi, Pb)-2223. The radii ionic of Ca^{+2} (1.06 Å) and Nd^{+3} (1.109 Å), the tenancy of Nd ions is the Ca site in the crystal (Aloysius, 2005).

Table.1, shows a decreasing of the lattice parameters *a* and *c* after x= 0.2. Indeed, this behavior agreed with Aloysius (2005).

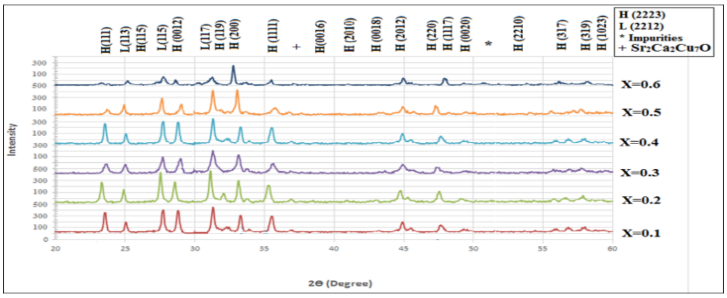

Figure.1. X-ray diffraction patterns of doped nanoparticles $Bi_{1.7}Pb_{0.3}$ $Nd_xSr_2Ca_2Cu_3O_{10+\delta}$ bulk samples sintered at 835°C for 140 hr.

Table.1. Values of lattice parameters, volume of unit cell and Volume fraction of Bi-(2223) and Bi-(2212) at sintering temperature 835 °C for different composition of $Bi_{1.7}Pb_{0.3}$ $Nd_xSr_2Ca_2Cu_3O_{10+\delta}$ bulks.

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x	a (Å)	b (Å)	c (Å)	V(Å)^3	c/a		T_c (K)	Volume fraction of phases formed (%)	
								Bi-2223 phase	Bi-2212 phase
0.1	5.431	6.425	37.084	1294.015	6.828	0.669	111	78.571	21.428
0.2	5.450	5.442	37.172	1102.480	6.820	0.858	113	83.333	16.666
0.3	5.412	5.422	37.126	1089.420	6.859	0.814	111	76.923	23.076
0.4	5.376	5.350	37.115	1067.486	6.903	0.752	110	78.571	21.428
0.5	5.355	5.395	37.108	1072.058	6.929	0.458	110	75	25
0.6	5.358	5.304	36.905	1048.796	6.887	0.325	109	72.727	27.272

Fig.3, expressions the variant of resistivity with temperature of $Bi_{1.7}Pb_{0.3}Nd_xSr_2Ca_2Cu_3O_{10+\delta}$ samples. From the figure, all the compositions are superconductors with one-step transition although a complete zero-resistance could be observed. The higher T_c =113 K at x=0.2 with. However, the enhancement of the T_c could be attributed to increase the contact between the grains and the growing of 2223 -high T_c phase during the sintering process time. Moreover, this could characteristic to a decrease in oxygen content δ, leaves vacant sites. This might be increased to grain boundaries and act as poor contact within the 2223-phase. Such grain boundaries would occur at some stage as a crystallization decomposition process of the high-T_c phase at high sintering temperature.

The adding for Pb^{2+} (1.19) in Bi^{3+} (0.96Å) sites is to release the internal stress (Ikeda,1988), also the adding for Pb to the compounds may lower the modulation by influencing the charge balance, structural of the relevant layers (Maeda and Tagano, 1996).

The important argument which incidental from the results above, the adding of Pb on Bi sites and doping the nanoparticles with Nd in combination which specifies the development of links on intergranular interfaces of high temperature 2223-phases. The enhancement of T_c can achieve by appropriate amount of added nanoparticles in Bi-2223, which led to the improvement in electric connection between superconducting grains.

The results indicate that development of samples with a small amount of the addition acts as the effective pinning centers of the fluxes in the samples Nd nanoparticle more than 0.2 reduced the intergranular coupling and increased weak link behavior by increasing impurity phases, similar results mentioned (Aloysius, 2005; Hamid, 2000). In addition, nanoparticle block the intergrain spaces, as a result reinforcing the join between grains. The decreasing of δ and T_c as nanoparticles Nd concentrations increasing from 0.3 to 0.6 wt.%. The explanation through the charge-ordering phenomenon, maybe induced by Pb and Nd as a pair breaker accompanied by changes in oxygen content or oxygen order effects that decrease the numeral of holes in the lattice from the optimum value (Shatkovskis, 2000). The reason behind improving the T_c, the local assembly of the BiO layer considered tobe altering by increasing the quantity of oxygen atoms. Therefore, the additional oxygen attracts electrons from the CuO plane, in that way, the creation of holes will shorten the Cu-O_2 bond length (Abbas, 2012; Khaled, 1997). In other hand, the decreasing of the average valance of Cu and the average CuO_2-plane hole concentration in BiPb-2223 occurred by substitution by Pb. Therefore, the reduction of T_c was argued to be out of plane addition of Pb for Bi where it shows a longer wavelength of structural modulation (Salamati, 2010).

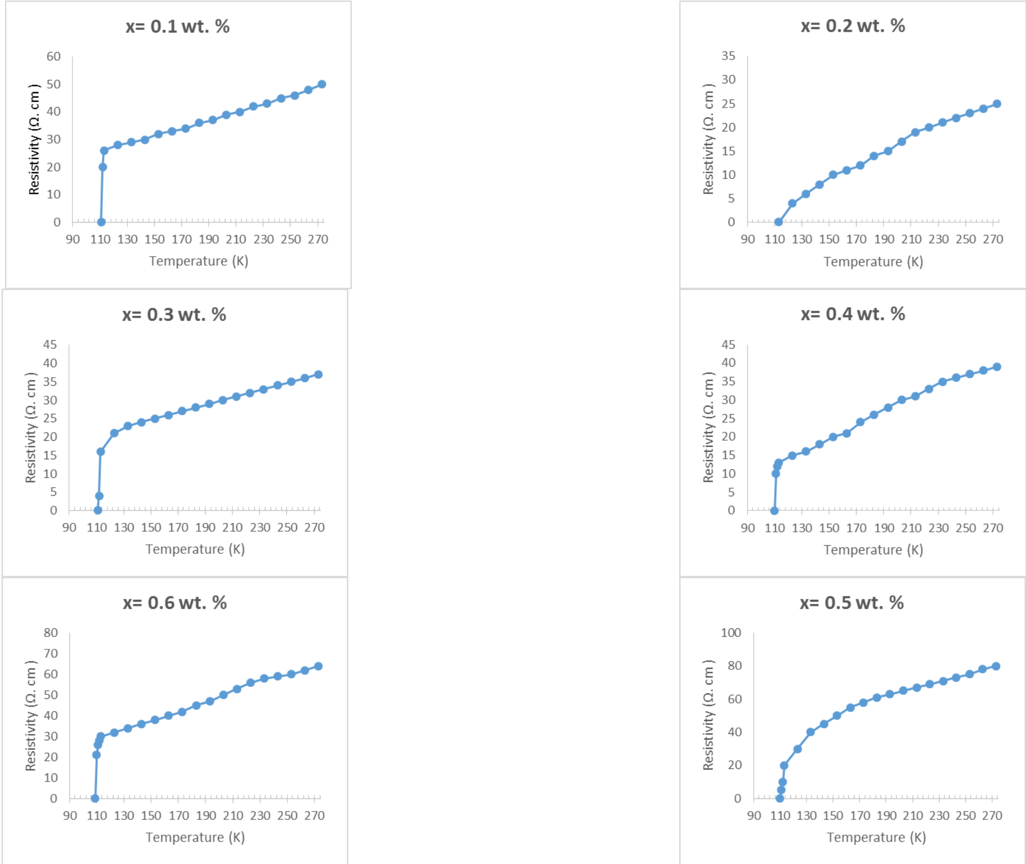

Figure.2. Resistivity (ρ) as a function of a temperature for bulk samples for different concentration of nanoparticles $Bi_{1.7}Pb_{0.3}$ $Nd_xSr_2Ca_2Cu_3O_{10+\delta}$.

4. CONCLUSIONS

XRD analyses presented the orthorhombic structure for all samples with two superconducting phases. The maximum transition temperature was 113 K with a higher volume fraction 83.3 % of Bi-2223 and the maximum value of oxygen content was 0.858 which was found for the composition at x = 0.2.

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