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

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Abstract

The prepared Superconducting samples achieved by a conventional solid-state reaction method and methodically deliberate for their superconducting properties. The Nd_2O_3 nanoparticles concentration x varied from 0.1 wt% to 0.6 wt%. Studying the effect of Nd nanoparticles (50 nm) on the physical properties of superconducting phase. The sightsaw of phase structural characteristics of synthesized thin films samples through powder X-ray diffractometer and 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 standard DC four-probe method was used to measure the critical transition temperature (Tc) and found to have optimal value at x=0.2 wt%, which had a maximum enhancement in Tc for samples.

Keywords:* *(Bi, Pb)-2223; Nd nanoparticle;, solid state reaction

Introduction

The most essential discovery of the Bi-Sr-Ca-Cu-O (BSCCO) superconducting system was achieved by Maeda [1], which considered to be very important for practical applications meanwhile it has a large chemical resistance against moisture and stable in atmospheric pressure. For these reasons, many researchers study this system. Chen et al. [2] studied the superconductivity and microstructure of BSmCCO samples with the addition of small amounts of 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 Jc for the Nd doped samples could be attributed to the higher peritectic temperature, the higher solubility of Nd in liquid phase, and the larger size of Nd ions. Aloysius et al. [3] studied Phase evolution and superconducting properties of Nd added (Bi, Pb)-2223 superconductors in bulk form. The amount of Nd was varied from 0.005 to 0.030 on a general stoichiometry of Bi:Pb:Sr:Ca:Cu=1.85:0.35:2.0:2.1:3.1. Critical current density of all the samples was higher than that of the pure sample and it is more than twice for the sample with Nd=0.020. XRD analysis showed the presence of Bi-2212 even after the last stage of sintering for the samples with Nd=0.020 and 0.030.

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Microstructural analysis revealed that the morphology and texturing of all the samples are identical with a slight improvement for the Nd added samples.

It is likely that Nd may be substituted at Ca or Sr sites creating point defects, which act as flux pinning centers. Ozkurt et al. [4] 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 obtained results suggest that with increasing Nd^{3+} doping for Pb^{2+} the (2223) phase existing in undoped BSCCO gradually transforms into the (2212) phase and hence all of the samples have a mixed phase formation. The R-T result of the samples show two-step resistance transition; first transition occurs at 100 K and second in an interval of 80-90 K, depending on the Nd concentration. The magnetization decreases with increasing temperature in agreement with the general characteristic of the high-Tc materials.

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

Materials and Methods

$Bi1_{.7}Pb_{0.3}Nd_xSr_2Ca_2Cu_3O_{10+\delta}$, bulk samples for x equals to (0.1, 0.2, 0.3, 0.4 0.5 and 0.6 were prepared by solid state reaction using appropriate weight of high purity 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 were mixed together using agate mortar. A sufficient quantity of 2-propanol was added to form a paste during the process of grinding for about 1 h, to get a homogeneous mixture. Later the mixture was calcined in air at 800°C for 24 h. Then it was pressed into disk-shaped pellets 13 mm in diameter and 1 mm to 2 mm in thickness using a manual hydraulic press type (SPECAC) under pressure 0.7 GPa. The pellets were sintered in air at 835°C for 140 h. 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.

Results and Discussion

The crystal structure of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ doped with Nd nanoparticles samples sintered at 835°C with different composition (x=0.1, 0.2, 0.3, 0.4, 0.5 and 0.6) were studied 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 presence 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 growth of Bi-2223 as the percentage of Nd increases. In addition, no secondary phase has been observed which includes Nd ions. This shows that the Nd ions enter into the crystal structure of (Bi, Pb)-2223. Comparing the ionic radii of Ca^{+2} (1.06 Å) and Nd^{+3} (1.109 Å), the most probable occupancy of Nd ions is the Ca site in the crystal [3].

TABLE 1 shows a decreasing of the lattice parameters *a* and *c* after x=0.2. Indeed, this behavior agreed with Aloysius et al. [3]. Moreover, increasing behavior of *c* parameters with Nd nanoparticles concentration could be interpreted as: heat treatment changes the oxygen content that is combination with added materials strongly altered superconducting properties, including increase of the super fluid density, which means Nd increases flux of the super fluid density.

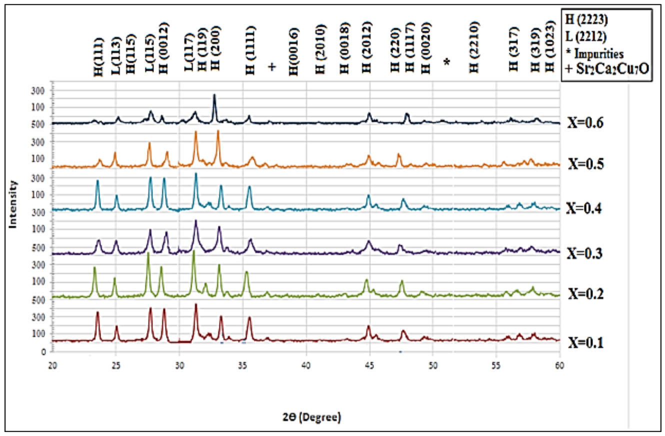

FIG. 1. **X-ray diffraction patterns of doped nanoparticles $Bi_{1.7}Pb_{0.3}$ $Nd_xSr_2Ca_2Cu_3O_{10+\delta}$ bulk samples sintered at 835°C for 140 hr.**

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

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 Bi1.7$Pb_{0.3}$ $Nd_xSr_2Ca_2Cu_3O_{10+\delta}$ bulks.**

FIG. 2 shows the variation of resistivity with temperature for the samples of doping $Bi_{1.7}Pb_{0.3}$ $Nd_xSr_2Ca_2Cu_3O_{10+\delta}$. From the figure, all the compositions are superconductors with one-step transition although in all cases a complete zero-resistance could be observed. The higher T_c=113 K at ×=0.2 with. However, the enhancement of the T_c could be attributed to increase the contact between the grains and the growth 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 may give rise 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 addition of Pb^{2+} (1.19) in Bi^{3+} (0.96Å) sites is to release the internal stress [5], also the addition of Pb to the compounds may lower the modulation by influencing the charge balance, structural of the relevant layers [6].

The important argument which can be inferred from the results above, the addition of Pb on Bi sites and doping the nanoparticles with Nd in combination which specifies the improvement 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 the improvement of the samples, suggesting that a small amount of the doping acts as the effective pinning centers of the fluxes in the samples Nd nanoparticle doping more than 0.2 reduced the intergranular coupling and increased weak link behavior by increasing impurity phases, similar results mentioned by [7,8]. In addition, nanoparticle can fill the intergrain spaces, and thereby reinforce the coupling between granules. The decreasing of δ and T_c as nanoparticles Nd concentrations increasing from 0.3 wt% to 0.6 wt%. The explanation through the charge-ordering phenomenon, maybe induced by Pb and Nd as a pair breaker could be accompanied by changes in oxygen content or oxygen order effects that decrease the number of holes in the lattice from the optimum value [9]. The reason behind improving the T_c, the local structure of the BiO layer considered to be altering by increasing the amount 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 [10,11]. 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 [12].

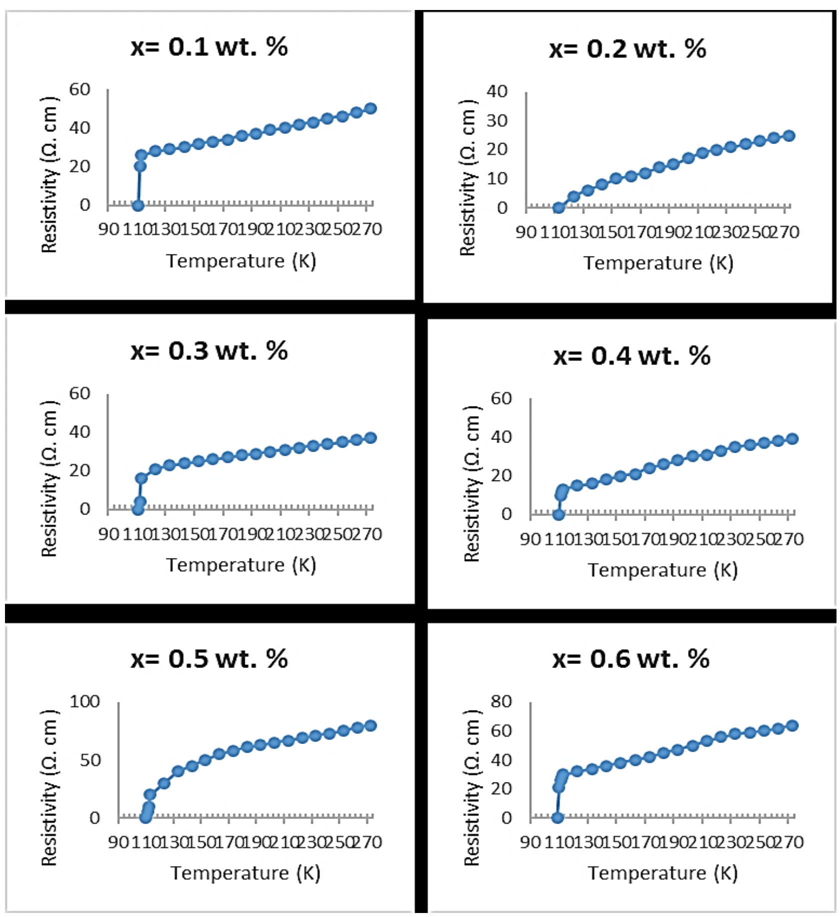

FIG. 2. **Resistivity (ρ) as a function of a temperature for bulk samples for different concentration of nanoparticles $Bi_{1.7}Pb_{0.3}Nd_xSr_2Ca_2Cu_3O_{10+\delta}$.**

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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