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Research Article

Improvements of Electrical Properties of $Bi_{2-y}cd_ySr_2Ca_2Cu_3O_{10+\delta}$ Annealed Ceramic by Bismuth partial substitution by Cadmium

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Abstract.

In this paper, four samples of $Bi_{2-y}cd_ySr_2Ca_{.2}Cu_3O_{10+\delta}$ with y= 0.1, 0.2, 0.3 and 0.4 have been prepared by solid state reaction process. The powder was pressed to pellets with one cm diameter under a hydrostatic pressure about (8 tons/cm^2). The pellets were put in a furnace which has a programmable controller for sintering in air at 855–860 ◦C for 72 hours with a rate of `100 °C /hours and then were cooled to room temperature by same rate of heating. Electric resistivity was studied using the four probe technique to find the transition temperature at zero resistivity ($T_{c(\mathrm{off})}$) and on set ($T_{c(\mathrm{on})}$), The transition temperature $T_{c(\mathrm{off})}$ and $T_{c(\mathrm{on})}$ were increasing from 106 to 131 K and 113 to 138 K by increasing cadmium from 0 to 0.4, respectively. X-ray diffraction (XRD) analysis showed all our samples have orthorhombic structure correspond to the 2223 phase, with changing of the intensity by increasing cadmium concentration.

Keyword: solid state reaction process, Electrical properties, four probe technique and X-ray diffraction.

1. INTRODUCTION

The phenomenon of superconductivity is a physical phenomenon that occurs when certain conditions of temperature, current density, and magnetic field meet and under intense cooling, which provides a fast and ideal path for the transmission of charge carriers away from any obstruction or obstruction of the electric current inside the material. Superconducting materials are considered one of the most promising materials in high electrical and electronic performance applications [1]. In the case of superconductivity, the electrons are bound together to form pairs of electrons, and the formation of these pairs reduces the energy of these electrons. Note that in ordinary metallic materials the resistance gradually decreases with lower temperatures, and that impurities present in conductive materials such as silver and copper are the ones that impede and counteract the achievement of the lowest level of resistance at low temperatures, but in the case of superconductivity, the most important characteristic of superconducting materials sudden decrease in the value of the resistance as it quickly and suddenly drops to zero when the material is cooled to a temperature below its critical temperature, where electrons behave at the microscopic level in superconducting materials in a very different way from that found in ordinary metals [2]. The discovery of high-temperature superconducting ceramic compounds (HTSC) sparked the first spark for a new revolution in materials technology science and industrial applications. It is worth noting that the study of methods and processes of substitution or addition of elements can give us and open up more horizons for us in understanding the mechanisms by which superconductivity occurs in the elements and compounds, especially those that depend on their composition on copper oxide [3].

After the first discovery of the La-Ba-Cu-O superconducting ceramic system with a critical transition temperature of (30-40) K, other families of ceramics based on copper oxide were manufactured with higher critical temperatures "Tc" [4]. These oxides include the Bi-Sr-Ca-Cu-O chain (Tc = 80-110 K) [2]. The Bi-2223 phase is represented as an interesting phase of the Bi-Sr-Ca-Cu-O system, as it is characterized by a superconducting critical temperature and high critical current density [3]. Also, some superconducting properties of bismuth, mercury, or thallium based compounds can be improved by adding some chemical elements to these compounds or by partially replacing some of their elements with other elements from the periodic table [7-9]. These additions have improved the electrical and structural properties. Partial substitution techniques are a powerful tool for evaluating the effect of defects on superconductors, as they play a fundamental role in rearranging the atoms of a compound, eliminating sample variation problems [10-14].

In this report, we present a study on the effect of partial substitution of cadmium on the structural and electrical properties of annealing $Bi_{2y}cd_ySr_2Ca_{.2}Cu_3O_{10+\delta}$ with y= 0.1, 0.2, 0.3 and 0.4 superconducting samples prepared by the solid-state reaction method.

2. EXPERIMENTAL

The synthesis of Bi : 2223 annealing samples with chemical formula $Bi_{2y}cd_ySr_2Ca_{.2}Cu_3O_{10+\delta}$ with y= 0.1, 0.2, 0.3 and 0.4 have been performed by solid state reaction method, using appropriate weights of pure powders of BiO, $SrNO_3$, CaO, CdO and CuO, as starting materials. The weight of each reactant was measured by using a sensitive balance. The powders BiO, $SrNO_3$, CaO, cdo and CuO, were mixed together by using agate mortar to grind for about 30-50 minute. The mixture was put in furnace that has programmable controller, for calcinations, which is the heat treatment to remove NO_2 and CO_2 gases from the mixture. For this process the powder was heated to temperature of 800 ˚C for three hours. The powder was reground again, pressed to pellets with one cm in diameter under a hydrostatic pressure about (8 tons/cm^2). The pellets were then put in a furnace which has a programmable controller for sintering in air at 855–860 ◦C for 12 h with a rate of 100 ˚C /hours and then they were cooled to a temperature of 400 degrees for a period of 6 hours for the purpose of annealing. Then the samples were cooled to room temperature. by same rate of heating. The ρ –T (resistivity vs. temperature) characteristics of these samples were measured by means of a standard d.c four-probe technique to investigate their superconducting state. The critical temperatures has been described elsewhere [12, 13]. The structure of the prepared samples was obtained by using X-ray diffraction meter (XRD) measurements in θ-2θ arrangement, in a range from 10 to 80 degrees. A computer program, based on Cohen's least square method [14], was used to calculate network parameters a, b and c.

3. RESULTS AND DISCUSSION

The samples were examined with an X-ray diffraction device. Figure 1 shows the X-ray diffraction pattern of the pure and partially cadmium-substituted $Bi_{2-y}cd_ySr_2Ca_{.2}Cu_3O_{10+\delta}$ superconducting system with y=0.1, 0.2, 0.3 and 0.4. The X-ray diffraction (XRD) patterns of the Bi-doped superconductor are shown in Fig. 1. The locations and intensity of the diffraction peaks reveal that the samples possessed mainly from a primary phase 2223 in addition to a small percentage of the minority phase 2212 and a small amount of an indeterminate secondary phase. Comparison of the relative intensities of XRD patterns of Bi-doped samples with the relative intensities of the same sample reflections with y = 0.0 shows a phase decrease of 2212 and an increase of phase 2223 with an increase of Bi-doped. The network parameters of the Bi-2223 stage were calculated using d-values and reflections (hkl) of the X-ray diffraction pattern observed by a program based on Cohen's least-squares method. The parameters obtained for the samples presented in the table indicate that all of them possess an orthorhombic structure. The lattice constant of the c and c / a axis increases with increasing cadmium compared to the sample without cadmium content. This result can be explained by the difference in the ionic radii of both bismuth and cadmium [15, 16]. The lattice constant of the c axis and the mass density ρ_M are summarized for the different ratios of cadmium in the table. As shown in this table, an increase in cadmium to an increase in the mass density as shown in figure 2.

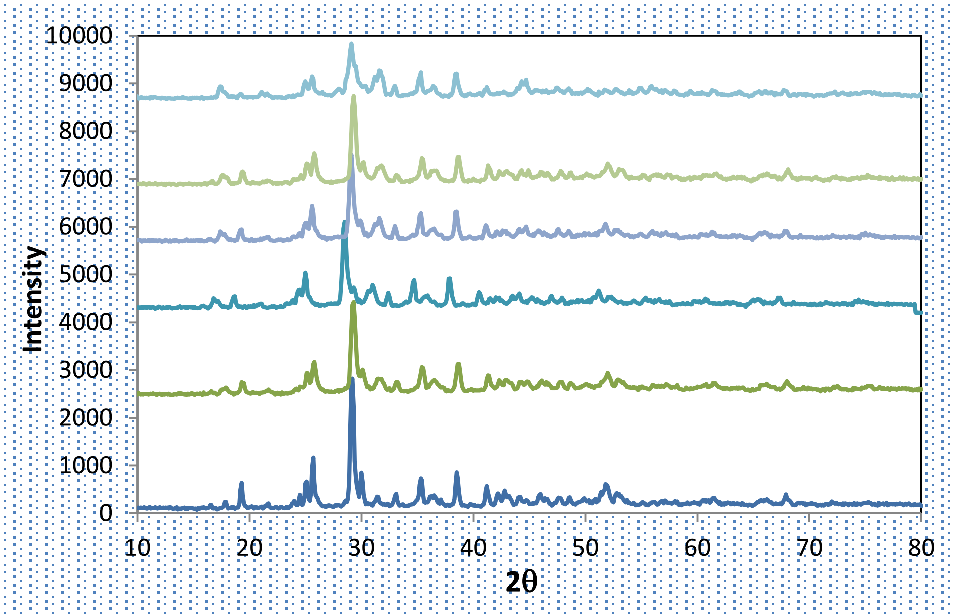

Figure1. XRD patterns of $Bi_{2-y}cd_y\ Sr_2Ca_2Cu_3O_{10+\delta}$ samples (y = 0.0, 0.1, 0.2, 0.3 and 0.4).

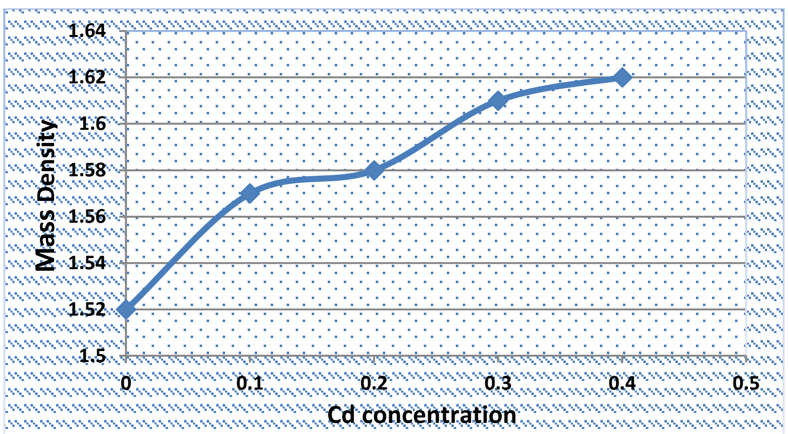

Figure2. Mass density as a function of Cadmium concentration for $Bi_{2-y}cd_y\ Sr_2Ca_2Cu_3O_{10+\delta}$ samples (y = 0.0, 0.1, 0.2, 0.3 and 0.4).

The temperature dependence of the temperature resistance function of the $Bi_{2-y}cd_y\ Sr_2Ca_2Cu_3O_{10+\delta}$ samples (y = 0.0, 0.1, 0.2, 0.3 and 0.4). are shown in Figure 3. Figure 3 illustrates the relationship between electrical resistance and temperature. The resistivity of all samples have metallic behavior with increasing cd content, the normal state resistance of the changes to superconducting state when the temperature of the samples decreasing. Critical transition temperature at zero resistance $T_{c\ (off)}$ = 106. 111. 122, 128 and 131 K, and transition temperature Tc (on). = 113, 117. 127, 133 and 138 K for y = 0.0, 0.1, 0.2, 0.3 and 0.4, respectively. The critical temperatures are summarized for the different ratios of cadmium in the table. As shown in this table, an increase in cadmium leads to an increase in the critical temperatures.

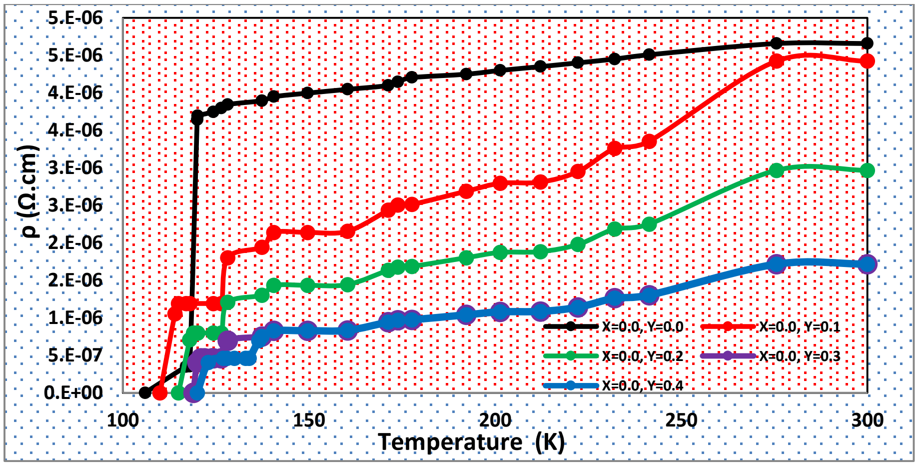

Figure 3. The resistivity as function temperature for for the $Bi_{2-y}cd_ySr_2Ca_{.2}Cu_3O_{10+\delta}$ samples

Table: Values of critical transition temperature, lattice parameters (a, b, c,), and mass density ρ_M for the $Bi_{2-y}cd_ySr_2Ca_{.2}Cu_3O_{10+\delta}$ samples.

samples	$T_{(off)}$ (K)	$T_{(on)}$ (K)	*a* (Å)	*b* (Å)	*c* (Å)	ρ_M (g/cm^3)
0	**106**	**113**	**5.437**	**5.427**	**37.21**	**1.52**
0.1	**111**	**118**	**5.423**	**5.415**	**37.37**	**1.57**
0.2	**122**	**127**	**5.409**	**5.402**	**37.42**	**1.58**
0.3	**128**	**133**	**5.404**	**5.401**	**37.46**	**1.61**
0.4	**131**	**138**	**5.404**	**5.402**	**37.49**	**1.62**

4. CONCLUSION

Five samples of Bi-based polycrystalline $Bi_{2-y}cd_y\ Sr_2Ca_2Cu_3O_{10+\ \delta}$ with y = 0.0, 0.1, 0.2, 0.3 and 0.4, were synthesized by solid state reaction method. By increasing cadmium concentration the content of Bi-2223 phase increase and the content of Bi-2212 phase decrease. XRD analysis show that all samples have orthorhombic structure. It was found that the increase of cadmium concentration produce increase of c-axis lattice constant, and the mass density ρ_M increases by increasing cadmium content. The partial substitution of Bi with cadmium to be increase of critical transition temperature $T_{c(off)}$ and $T_{c(on)}$.

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