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The Influence of Bi on Compounds on Their Structural and Electrical Properties

The high-temperature superconductivity of $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10}$ and its electrical resistivity were measured at temperatures ranging from 90 to 330K. According to the findings, when the Bi ions concentration is increased from 0.1 to 0.5, the zero resistivity's critical temperature rises from 121 to 146K. The x-ray diffraction has also been used to analyze the structure of the $Tl_2Bi_2Ba_2Ca_2Cu_3O_{10}$ compound. The analysis revealed that the compound structure type is tetragonal with a=b=5.36Å and c=36.09Å. In addition, the value of the c-axis increases to 37.8Å when the Bi ions concentration is elevated to 0.5.

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1. Introduction

Since the discovery of mercury, there has been a great deal of interest in extremely high-temperature (HT) superconductivity in copper oxide. Initially, the first participant in the $HgBaCa_{n-1}Cu_nO_{2(n+2+8)}$ series has n=1, 2, 3, 4, and 5 and crucial temperatures Tc=94, 128, 135, 116, and 96 K, respectively [1,2]. Two more comparable HT superconductivity series with Tc>100K received undue attention. The first was the super conductivity about 105 K shown by the Bi-Sr-Ca-Cu-O compounds [3,4]. The systems shown above proved that the Tc values of the structural formulation superconductors $Bi_2Sr_2Ca_2Cu_3O_{10}$, $Bi_2Sr_2Ca_2Cu_3O_8$, and $Bi_2Sr_2Ca_2Cu_3O_6$ are 120, 110, and 108.5 K, respectively [5]. On the other hand, second series TI-Ba-Ca-Cu-O compound demonstrated superconductivity above 100 K [6]. The greater Tc of this series of superconductors gives them infinite X significance. The Tc values of $Tl_2Bi_2Ba_2Ca_2Cu_3O_6$, $Tl_2Bi_2Ba_2Ca_2Cu_3O_8$, and $Tl_2Bi_2Ba_2Ca_2Cu_3O_{10}$ compounds were found to be 80, 110, and 125 K, respectively. There are other series that exhibit superconductivity above 130 K when Hg is used in place of Tl. More investigation was done on the Hg-Ba-Ca-Cu-O combination, which resulted in increased Tc at 150K when subjected to pressures as high as 150 bar [7]. Given that the primary determinants of site tenancy in replacement studies are the valence state ionic radius and the ionic radius coordination number. The replacement effects in these materials have received a lot of interest in HTSC studies [8,9]. Here are some key points that highlight the significance of the substitutional results: (a) A number of replacement investigations lead to an increase in the materials' low Tc. New superconductors discovered at HT (b). (c) Can enable a more thorough comprehension of the HT superconductivity mechanism. Nearly all high Tc systems are made of co-based materials, which have two key characteristics: (a) A crystal structure that is partially or entirely orthorhombic or tetragonal with a high C-parameter value. (b) The cause of HT superconductivity in these systems is thought to be the very conducting 2D Cu-O layers.

The aim of this work is to investigate the effects of Bi substitution instead of Tl on the electrical resistivity in the HT and Tc of $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10}$ superconductors.

2. Experimental Part

Samples of HT superconducting technology were produced using solid state reaction technology of the $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10}$ compounds (where x=0, 0.1, 0.2, 0.3, 0.4, and 0.5). The correct stoichiometric ratio of Ba, Ca, and Cu is 2:2:3. With the help of the isopropanol fluid, these ingredients were combined, ground in a manually operated gate mortar, and thoroughly dried for 20 minutes at 60°C. For 12 hours, the appropriate mixture of these oxide powders was heated in an electric resistance furnace to 950°C. The resulting mixture was then further ground and compressed into pellets with a radius of 1.4 cm and a thickness of 0.1 cm while operating at a pressure of 3 tons per square centimeter. For 30 hours, the pellets were sintered in an oxygen gas stream at a flow rate of 1.1 liters per hour at 850°C. After that, the pellets were cooled at a rate of 30°C per hour to reach room temperature. Conventional four-probe method used to find the electrical resistance. Using conductive silver paste, the samples and probes were connected by thin copper wires. The samples are being cooled to a low temperature using a closed cycle helium refrigerator. Those samples were subjected to room-temperature x-ray diffractometer (XRD) analysis utilizing a Phillips device equipped with a Fe K-α source and a wavelength 1.937Å.

3. Results and Discussion

The expected Tc_0 values along with the resistance drop's midpoint temperature displayed in table (1). The electrical resistivity of $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10}$ compounds was evaluated in response to temperature for x = 0, 0.1, 0.2, 0.3, 0.4, and 0.5, as shown in Fig. (1). Using the MATLAB computer language, the lattice parameters values of the a, b, and c were determined and are provided in table (2). The transition temperature of superconducting (Tc_0) is the temperature at which the sample resistance drops to zero. The sample that yielded the ideal Tc_0 value was the one when x=0.5. The fluctuations in the superconducting electron carrier density are responsible for the rise in Tc values seen in those samples. Moreover, the normal spacing between the Bi ions in the network matrix coherence length in the c-direction and at the a-b planes is impacted by partial replacement of Bi rather than TI. These effects facilitate easier movement in the direction of a to b for the 2D Cu-O planes, which govern HTSC. Higher Tc values must follow from a fractional substitution of Bi in TI. Furthermore, the resistively temperature curves' slope is not much altered, even if increasing the x-value to 8.5 seems to have a large effect on Tc values. These patterns suggest a transition mechanism based on electron-phonon interaction. Increases in Tc values resulting from partial substitution of Bi in TI-Ba-Ca-Cu-O compounds have been associated with changes in the superconducting electron carrier density. These changes change the usual ion spacing in the network matrix, with the coherence length of the a-b planes in the c-direction aiding simpler movement in the Cu-O planes and increasing Tc values [11].

Table (2) Values of lattice parameters a, b, and c were calculated using the MATLAB programming language

Sample composition	Lattice parameters (Å)			Tc (K)	
	a	b	c	Tc_o	Tc_m
$Tl_2Bi_2Ba_2Ca_2Cu_3O_{10}$				125	125
$Tl_{1.9}Bi_{0.1}Ba_2Ca_2Cu_3O_{10}$	5.361	5.361	36.12	121	136
$Tl_{1.8}Bi_{0.2}Ba_2Ca_2Cu_3O_{10}$	5.361	5.361	36.22	129	145
$Tl_{1.7}Bi_{0.3}Ba_2Ca_2Cu_3O_{10}$	5.362	5.362	36.56	133	147
$Tl_{1.6}Bi_{0.4}Ba_2Ca_2Cu_3O_{10}$	5.361	5.361	37.67	137	149
$Tl_{1.5}Bi_{0.5}Ba_2Ca_2Cu_3O_{10}$	5.361	5.361	37.80	146	156

According to this, increasing Tl with Bi results in higher c-values, which makes electron mobility across the Cu-O planes of those compounds easier. At 0.5 Bi in Tl, it seems that the substitution worked. For the compound $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10}$, adding more than 0.5 Bi concentration causes the Tc values to drop towards 133 K [12]. Table (2) displays the values of the a, b, and c parameters. As the Bi concentration grows, so does the length of the c-axis in comparison to the lengths of the other cell sides. The findings are interpreted as follows. There will be few opportunities because the TI roles are not entirely filled. According to the first idea, cations such as Bi can reside in such regions, increasing HT superconductivity. The c-axis values reported in this study are in good agreement with the findings for the Bi-2223 compounds, which demonstrate a linear increase in Tc values with compound-level Pb concentration. Results of partial substitutions of Sn, Eu, and Zn in Ba, Sm, and Cu metals for the crystal structure, transition temperature, and oxygen concentration of the HT $SmBa_2Cu_3O_7$ superconductor [13-15]. These results showed that the limited replacement of Eu and Sm metals increased the Tc from 88 to 107 K without changing the type crystal structure. In contrast, the limited replacement of Sn and Ba metals resulted in lower Tc values and a different shape of the crystal structure. The orthorhombicity and superconductivity of the structure were lost when Cu was replaced with Zn metal.

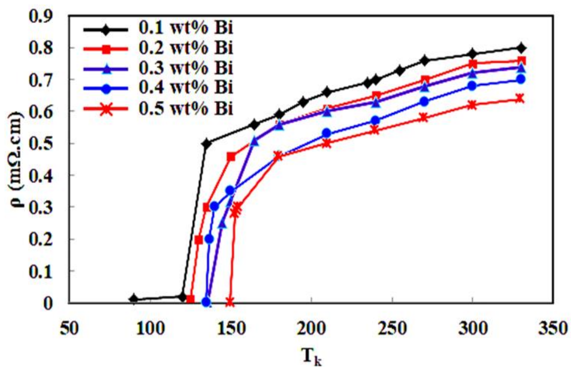

Fig. (1) The temperature dependence of electrical resistivity for varying Bi wt.%

4. Conclusion

High-temperature $Tl_{2-x}Bi_xBa_2Ca_2Cu_3O_{10}$ superconductors have had their electrical resistivity tested in the 90-330 K temperature range. The following points serve as a summary of the primary findings. As the concentration of Bi rose from zero to 0.5, the critical temperature rose from 121 to 146 K. The lattice parameters of the crystal structure, a=b=5.36Å and c=36.09Å, were determined to be tetragonal. When the c-axis is raised to 0.5 elevation, its magnitude rises to 37.8Å.

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Table (1) Lattice parameter values as the Bi concentration increases

T (K)	ρ (mΩ.cm) x=0.1	T (K)	ρ (mΩ.cm) x=0.2	T (K)	ρ (mΩ.cm) x=0.3	T (K)	ρ (mΩ.cm) x=0.4	T (K)	ρ (mΩ.cm) x=0.5
330	0.8	330	0.76	330	0.74	330	0.7	330	0.64
300	0.78	300	0.75	300	0.72	300	0.68	300	0.62
270	0.76	270	0.7	270	0.68	270	0.63	270	0.58
255	0.73	240	0.65	240	0.63	240	0.57	240	0.54
240	0.7	210	0.61	210	0.60	210	0.53	210	0.5
235	0.69	180	0.56	180	0.56	180	0.46	180	0.46
210	0.66	150	0.46	165	0.51	150	0.35	155	0.3
195	0.63	135	0.3	150	0.32	140	0.3	154	0.29
180	0.59	130	0.2	145	0.25	137	0.2	153	0.28
165	0.56	125	0.01	136	0.00	135	0.0	150	0
135	0.5								
120	0.02								
90	0.01								

