THE INFLUENCE OF Pb,AL DOPED ON THE HIGH-TEMPERATURE SUPERCONDUCTOR (Bi2-Sr2-Ca2-Cu3-O10+Δ)

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Abstract

A ceramic superconductor compounds with the composition Bi₂Sr₂Ca₂Cu₃O₁₀⁺δ were prepared alone or substituted by Pb doped (Bi₂₋ₓPbₓSr₂Ca₂Cu₃O₁₀⁺δ) samples with different values of x = (0.1, 0.35, 0.4), and Al doped (Bi₂₋ₓAlₓSr₂Ca₂Cu₃O₁₀⁺δ) samples with different values of x = (0.1, 0.2, 0.3). The solid state reaction method was used for samples preparation. From the principle routes like Bi₂223, Ca₂Cu₃O₇ and CuO with high purity 99.999%. Superconducting phase was achieved by sintering (860°C) for (16 hours). The slow cooling rate (1°C/min) was very important to the formation of superconducting time. The Bi-based system was multi phases. Different measurement such as resistivity measurement, X-ray diffraction (XRD) and Scanning Electron Microscope (SEM) were made to show the improvement in the superconductivity of the high phase. The crystal structures of stable superconducting compound of Bi₂Sr₂Ca₂Cu₃O₁₀⁺δ was orthorhombic with lattice constant a = 5.394 Å, b = 5.346 Å, c = 30.753 Å for low Tc phase and a = 5.394 Å, b = 5.311 Å, c = 37.182 Å for high phase. The critical temperatures (Tc) of the HTSC Bi₂Sr₂Ca₂Cu₃O₁₀⁺δ were obtained to be Tc value for the undoped sample and for Pb, Al doped systems respectively and Scanning Electron Microscope (SEM) images showed formation plate-like or flake-like texture phases in superconducting samples.

Keywords: (HTSC) High-Temperature Superconductor (Bi₂-Sr₂-Ca₂-Cu₃-O₁₀⁺δ)

1-Introduction

Since the discovery of the Bi-Sr-Ca-Cu-O superconducting compounds [1], a great deal of work has been done to prepare the high-Tc phase. The most common method used to synthesize these superconducting oxides is the solid state reaction method [1,2] which consists of the mixing nominal compositions of high purity compounds such as Bi₂O₃, SrCO₃, CaCO₃ and CuO, pelletization of calcined powder, under a pressure of 4-6 tons/cm² and heating the mixed powders for 10-20 h at 800-820 °C. The formation of single high-Tc Bi-2223 phase however is very difficult due to the appearance of other superconducting phases such as Bi-2212, or non-superconducting phases. The most effective methods to enhance the volume fraction of the high-Tc phase was found to be:

1-By starting from composition with surplus Ca and Cu than the possible ideal composition of Bi₂Sr₂Ca₂Cu₃O₈ [3], by prolong the sintering process which is necessary to

form extra layers of Cu-O₂ and Ca planes into the layer structure of the low -Tc phase.

2-The annealing in an atmosphere with low oxygen pressure [3,4] which is effective in lowering the reaction temperature, and enhancing the stability of the high - Tc.

3-The substitution of Pb for Bi [5,6] or the addition of Pb in the Bi₂Sr₂Ca₂Cu₃Oₓ [7] is very effective in increasing the high - Tc phase. It was found that Pb has a catalytic effect on the reaction to from the high - Tc phase, and a certain amount (about 0.3mole) of Pb to the Bi₂Sr₂Ca₂Cu₃Oₓ compound is necessary for the occurrence of this reaction [6]. Furthermore the Pb has a role in the stabilization of the high-Tc phase[5].

Uehara et al [7] studied the magnetic measurement of BiSrCaCu₂Oₓ, and they estimated the high- Tc volume fraction to be 21%. Kumakura et al [8] investigated the upper critical field of BiSrCaCu₂O₆ with Tc above 100K. They found that at zero fields, the majority of transition occurred above 103K and a zero resistivity was attained below 80K. But as the magnetic field increased, the low temperature portion of transition curve shifts to low temperature, resulting in a broad transition. Matsuoka et al [9] investigated the effect of In addition on the superconducting behavior of Bi-Sr-Ca-Cu-Pb-O system, and found no effect on the critical temperature, but is effective in increasing the volume fraction of the Bi₂Sr₂Ca₂Cu₃O₁₀ compound.

Wu et al [10] investigated the effect of sintering temperature and duration on the formation of the 110K phase, in samples of nominal compositions of (Bi₄₋ₓPbₓ) Sr₂Ca₂Cu₃Oₓ. They observed that the optimum compositional range for obtaining large fraction of high - Tc phase (Tc=105K) occurs between PbxBi-4457 and PbxBi-4468.

The Bi:2223 phase has attracted considerable interest due to its higher Tc and the potential for applications. One of the reasons for the low critical current densities Jc is the granular nature of this sintered HTS compound. It is difficult to prepare single phase material for Bi:2223 phase. The Bi:2212 was frequently observed as a major impurity phase in Bi:2223 samples because of its greater thermodynamic stability with respect to the Bi:2223 phase. The partial substitution of Pb in Bi sites enhances chemical stability and promotes the formation of the 2223 phase [11].

Kовалева et al [12] presented a systematic study of the c-axis lattice dynamics in Bi₂Sr₂Ca₂n₋₁Cu₃O₄₋₂n (n=1,2,3) cuprate superconductors ( Bi2201,Bi2212, and Bi 2223) based on spectral ellipsometry investigation on single crystal and he compared them with theoretical shell model calculation. The observation of the multilayer band splitting in the optimally doped trilayer cuprate Bi₂Sr₂Ca₂Cu₃O₁₀₄₋₈ (Bi2223) by angle-resolved photoemission spectroscopy is reported by Iedera et al [13]. They obtained values of energy gaps 43( m eV) and 60( m eV) larger than those for the same doping level of the double-layer cuprates, which leads the large value of Tc in Bi2223.

2-Experimental

2-1 Materials

The samples were prepared by the solid state reaction method using highly pure 99.999% powders of Bi₂O₃, SrCO₃, CaCO₃, CuO, with appropriate
weights in proportion to their molecular weights through the following chemical reaction. Three types of superconductors systems were obtained, namely Bi$_2$Sr$_2$Ca$_2$Cu$_2$O$_{10+8}$, Bi$_{2+}$Pb$_{2}$Sr$_2$Ca$_2$Cu$_2$O$_{10+8}$, and Bi$_2$Al$_x$Sr$_2$Ca$_2$Cu$_2$O$_{10+8}$. The preparation of ceramic superconductor by solid state reaction includes a series of stages as shown in the following: Measuring the weight of each reactants with the required amount, using sensitive balance with (4-digits), type (STATON)462AL.

2-2 The chemical reactions

The systems were prepared by mixing appropriate amount of the starting materials through the following chemical reactions:

1. The first system (Bi$_2$Sr$_2$Ca$_2$Cu$_2$O$_{10+8}$) with 2223 phase was prepared by mixing appropriate amounts of the starting materials through the following reaction Scheme (14):

   \[ \text{(BiO)}_2 \text{CO}_3 + 2\text{SrCO}_3 + 2\text{CaO} + 3\text{CuO} \rightarrow \text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+2} + 2\text{CO}_2 \]

2. The second system (i.e., Bi$_2$Pb$_2$Sr$_2$Ca$_2$Cu$_2$O$_{10+8}$) was prepared by mixing appropriate amounts of the starting materials through the following reaction:

   \[ \frac{1}{2} \text{BiO}_2 \text{CO}_3 + \frac{x}{2}\text{PbO} + 2\text{SrCO}_3 + 2\text{CaO} + 3\text{CuO} \rightarrow \text{Bi}_2\text{Pb}_x\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+8} + (3-0.05)\text{CO}_2 \]

3. The third system (Bi$_2$Al$_x$Sr$_2$Ca$_2$Cu$_2$O$_{10+8}$) was prepared by mixing appropriate amounts of the starting materials through the following reaction:

   \[ \text{(BiO)}_2 \text{CO}_3 + 0.5\text{Al}_2\text{O}_3 + 2\text{SrCO}_3 + 2\text{CaO} + 3\text{CuO} \rightarrow \text{Bi}_2\text{Al}_x\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+8} + (3-0.05)\text{CO}_2 \]

2-3 Sample preparation

The mixture for each specimen was prepared by homogeneously mixing and grinding prescribed amounts of powders into a gate mortar. Appropriate amounts of these powders were mixed with alumina mortar and pestle for (2 hours) in 2-propanol and dried. The calcinations process performed at (810°C) for (16 hours) by heating rate of 30°C/h, then cooled to room temperature, with a rate of 30°C/h, in order to remove the CO$_2$ from the mixture as gas and then crushed into fine powder. The calcinations and grinding procedure were repeated three times at least. That assured the complete evolving of CO$_2$ from the mixture. The resulting powder then was pressed into pellets by using cylindrical and the die has a stainless steel cylinder of (13mm) diameter and (1.5-1.8) mm thick using manually hydraulic press PERKIN-ELMER, under a pressure of (0.5 GPa). The mixture with the final step of sample preparation was high temperature treatment that causes particles of the materials to join together and gradually reduce the volume of pore space between them, the powder is compacted into a pellet shape with a certain pressure then powder particles will be in contact with one another at numerous sites, with significant amount of pore space between the particles.

In order to reduce the boundary energy, atoms are diffused to the boundaries, permitting the particles to be bound together and eventually causing the pores to shrink. If sintering is carried out for a long time the pores may be eliminated and the material becomes dense.

The programming data for this process include, the rate of heating (60°C/h) up to (860°C) for (16 hours) with the flow of oxygen gas of about (1.25)L/min and then
with slow rate of cooling (1°C/h) down to room temperature reached. Resintering the pellets for up to (860°C) for (16 hours) using the same method as above.

2-4 Doping process
The samples of (Bi2Sr2Ca2Cu2O10+δ) , (Bi2-xPbxBi2Sr2Ca2Cu2O10+δ) for x=0.1,0.35,0.4) and (Bi2Al1Sr1Ca2Cu2O10+δ) for x=0.1,0.2,0.8) At the end of the weight of the powder was measured. The mixture of the powder was grinded in agate mortar for 45 min with the presence of a suitable amount of 2-propanol. Then it was dried in the oven for an hour at temperature of 60°C, after the powder was pressed into pellets as explained above and sintered at a temperature of 860°C for 16 hours.

2-5 Sample testing
The critical temperature (Tc) of the superconducting sample has been measured by using the resistivity measurement carried out by four – probe technique, which is considered as a good method for studying the electrical behavior of superconducting materials and a good tool for determining the critical temperature, although the last sample was measured roughly by Meissner effect. In this method, a small current is passed through a sample and the voltage drop across it. The terminals distinct from those used for passing the main part of the current through the specimen, where voltage drop in both leads and contacts are the electrical contact to the sample were made with fine copper wires, adhered with silver paste. The cryostat system was used for the measurement of critical resistivity of the sample, with the presence of liquid Nitrogen. The cryostat was joined to a rotary pump to get a pressure of (~10^-3) mbar inside the cryostat. The oxygen content was determined by using a simple chemical method called" Iodometric titration ". The structure of the samples was obtained by using X-ray for grinded pieces of the samples adhered to glass substrate. The x-ray diffraction(XRD) type PHELIPS has been used with the following features (Source CuKα, Cu current 20mA, Voltage 40kV, wavelength 1.5405Å. Scanning speed 2θ/min). A computational program has been used to find the lattice parameter of the unit cell from the pattern of XRD. Fine powder were obtained by grinding the pieces of the samples, then adhered to glass substrate and examined by the X-ray diffract meter. Scanning electron microscope (SEM) type JEOL JSM 6400, has been used to study the surface morphology and grain size of the samples for the composition (Bi2Sr2Ca2Cu2O10+δ, Bi2-xPbxBi2Sr2Ca2Cu2O10+δ,

, Bi2Al1Sr1Ca2Cu2O10+δ).

3 -Results and Discussion
X-ray diffraction patterns of Bi2Sr2Ca2Cu2O10 compounds in figure (1) show that two phases with lattice parameter constant a= 5.394 Å, b=5.3462 Å and c=30.753 Å for low phase (90°K) whereas a= 5.394 Å, b=5.311 Å and c=37.182 Å for high phase (110°K). This is in agreement with the results of Sequeira (15).

Figure (2) shows that the samples doped with Pb oxide with no change on the structure behavior. However, 20 shifted to lower angle was observed. Besides an increase in peak intensity indicated that structure was stabilized but crystallization phase is more favored. Like other high Tc superconductors, the Bi-Sr-Ca-Cu-O system has a layer structure but with multiple planes. The structure are similar,
differing only in the number of \( \text{CuO}_2 \)-Ca-CuO \(_2\) slabs packed along the \( c \)-axis. The crystal structure of \( \text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}\) consists of three \( \text{CuO}_2 \) layers with double \( \text{Bi}-\text{O} \) layers. The two \( \text{Sr} \) cations between the \( \text{Cu}-\text{O} \) and \( \text{Bi}-\text{O} \) below and above layers, and two \( \text{Ca} \) cations between adjacent \( \text{Cu}-\text{O} \) layer which form a corner-shared square based \( \text{CuO}_2 \) pyramids of opposite vertices and the third layer (square planar) that is sandwiched between the first two.

The \( \text{Bi}_2\text{Sr}_{2.35}\text{Pb}_{0.65} \) system has a different behavior that \( \text{Tc(onset)} \) unchanged (120 K) but have more sharp drop with transition width (10 K) as in figure (3). But the lattice parameter is unchanged due to the influence of deformation that is because in doped sample with \( \text{Pb} \) it is assume that \( \text{Bi}-\text{O} \) layers are more flat due to substitution of \( \text{Pb} \) that leads to gain strength against the deformation while the increase in \( \text{Tc(zero)} \) by (10 K) is due to the increase in the crystallization exhibited by an increase in intensity as in figure (2).

Figure (4, 5) show the system doped with \( \text{Al} \), it states different influence with higher doping rate. At a higher doping rate (0.8\text{Al}) for \( \text{Bi}_2\text{Sr}_{2.35}\text{Pb}_{0.65} \) system that are deformed leads to the disappearance of the superconducting state and also the transition to semiconductor and the x-ray diffraction pattern shows decreased in \( c \)-axis to 33.379 Å. An explanation of the changes to the semiconductor-like may result from the localization of charge carries because of distortion in crystal structure formed by deformation. For low \( \text{Al} \) doping \( \text{Bi}_2\text{Sr}_{2.35}\text{Pb}_{0.65} \), there is a decrease in the \( \text{Tc(zero)} \) from (80 K) to (60 K) and then there are sharper drops as in figure (8) which is indicated by an increase in peak intensities XRD pattern. In this work, this case is explained by the tendency for localization of carriers, which are stimulated by disorder introduced as a result of deformation. This static defect is predominant in \( \text{Cu}-\text{O} \) and \( \text{Bi}-\text{O} \) layers because these layers are sensitive to producing the superconducting properties. The presence of \( \text{Pb} \) in the structure of \( \text{Bi}_2\text{Sr}_{2.35}\text{Pb}_{0.65} \) compound has a direct influence on increasing the high-\( \text{Tc} \) phase, which can be seen clearly in the X-ray diffraction pattern in figures 2 and 3. In the first one, the high-\( \text{Tc} \) phase reflection (008, 115, 113, 117) are created and the intensities of the reflection (0012, 119, 0011) are increased by the addition of \( \text{Pb} \). At the same time low-\( \text{Tc} \) phase reflections (008, 113, 115, 117 and 0012) are reduced, compared to the same reflections in figure (3) we conclude that \( \text{Pb}^{2+} \) ions may occupy the Bi-positions or the Ca positions and the presence of \( \text{Pb} \) in Bi positions enhances the structure stability of the superconducting phases. Our experiments also reveals that the addition of \( \text{Pb} \) lowers the optimum sintering temperature, required to form the high-\( \text{Tc} \) phase to about 848-850°C. This could be attributed to the presence of the \( \text{CaPbO}_4 \) phase in the system, which changes the kinetic process of the formation of the \( \text{Bi}_2\text{Sr}_{2.35}\text{Pb}_{0.65} \) system. \( \text{CaPbO}_4 \) melts at 822°C and thus induces a liquid phase below 850°C and increases drastically, through a dissolution process, the diffusion of the reactive species (\( \text{Ca}^{2+}, \text{Cu}^{2+} \)).

The resistivity of the sample was measured as a function of temperature using standard four probe technique. For the preparation \( \text{Bi}_2\text{Sr}_{2.35}\text{Ca}_8\text{Cu}_3\text{O}_{10} \) sample, the onset \( \text{Tc} \) is at 110 °K and the resistivity drops to zero at 90 °K.

Table (1) shows the resistivity(\( \rho \)) measurements vs temperature. In \( \text{Bi}_2\text{Sr}_{2.35}\text{Pb}_{0.65} \) system, it is found that the influence of deformation on the \( \text{Tc(onset)} \) not on \( \text{Tc(zero)} \) which decreases \( \text{Tc(onset)} \) from (125 K) to (120 K). That refers to un stability.
in this phase with this rate of doping as in figure (6).

A computer program was used as a helpful tool for the determination of the cell parameters. X-ray diffraction patterns for different values of x. It can be noticed that the samples are a mixture of a major high $-T_c$ phase and minor low $-T_c$ phase. The intensity of the high-$T_c$ phase reflections is greater and the peaks are sharper than those of the low-$T_c$ phase.

Mizuno et al.\cite{18} reported that effective methods to increase the volume fraction of high-$T_c$ phase for Pb-Bi-Sr-Ca-Cu-O system are starting from nominal compositions with more Ca and Cu than in Bi-2223, and the addition of Pb to Bi-Sr-Ca-Cu-O system, and annealing at 870°C under higher oxygen pressure than 0.2 atm. Chavira et al.\cite{20} confirmed that the volume fraction of high $-T_c$ phase is rapidly increased, when a small amount of Pb is incorporated in the Bi-Sr-Ca-Cu-O system. They showed that the XRD patterns reveal the possibility for Pb to occupy Ca or Bi sites.\cite{21} Syno et al.\cite{22} showed that the XRD patterns and scanning electron microscope images of Bi$_2$Sr$_2$Ca$_2$Cu$_2$O$_{8+\delta}$ compound reveal a structure derived from the Bi$_2$Ti$_3$O$_7$ type in which double bismuth layers along the c-axis. The orthorhombic cell dimensions showed an approximate relation of $a=\sqrt{2}a$, $b=\sqrt{2}a$, and $c=8a$ where $a=3.82$ Å the parameter of a cubic perovskite and their appearance are similar to samples $n=3$. The oxygen content was determined by iodometric titration which is found in all samples for $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$, $(\text{Bi}_{1-x}\text{Pb}_x\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ for $x=0.1$, 0.35, 0.4) and $(\text{Bi}_{2-x}\text{Al}_x\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ for $x=0.1$, 0.2, 0.8). Table (1) shows the oxygen content for all samples, the excess oxygen in (2212) phase may reside in the double Bi-O layers in the lattice and by inserting a Cu-O$_2$ layer and Ca layer into(2212) phase for high $T_S$ and for long sintering time. The (2223) phase is formed which is a high $T_c$ phase. The double Bi-O layers in the (2212,2223) phases may play the role of reservoir for holes for the Cu-O$_2$ layers similar to the role played by the Cu-O chains in the YBa$_2$Cu$_3$O$_{6+\delta}$ phase. Finally, it was observed for the (2224) phase that $T_c$ is increased with increasing oxygen content. For (2212) phase an opposite effect for the oxygen content was observed.\cite{22}

Figure (7,8) shows the resistivity measurements vs temperature and values of $T_c =112K$, 120K, 125K and for the Pb doped for $x=0$, 0.1, 0.35, 0.4, and for the Al doped for $x=0$, 0.1, 0.2, 0.8). HTSC samples respectively. Surface Morphology, to compare the microstructure of pure and Pb, Al, doped-$(\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta})$ samples, micrographs were taken using JOEL JSM 4600 scanning electron microscope (SEM) operating at 15 kV. For better micro structural observations, the samples were polished, etched using a dilute HCl solution then coated with metal. Figure (9) shows the microstructure of pure Bi$_2$-Sr$_2$-Ca$_2$-Cu$_3$-O$_{10+\delta}$ sample and Figure (10) (1,2,3) show the microstructure of (Bi$_{1-x}$Pb$_x$-Sr$_2$-Ca$_2$-Cu$_3$-O$_{10+\delta}$) samples (0, 1, 0.35, 0.4) the samples doped Pb sintered 860°C showed needle-like structure between the flake-like grains that happened when (2223-Bi) and Figures (11,12,13) show the microstructure of (Bi$_{2-x}$Al$_x$-Sr$_2$-Ca$_2$-Cu$_3$-O$_{10+\delta}$) samples (0, 1, 0.2, 0.8), slowly cooled in O$_2$ atmosphere after sintering at 860°C. The micrographs clearly show that the size of the plates shaped-particles are in the range of $5-11$ μm. It was found that the grain growth of plate-like shaped increased rapidly with increasing Pb and Al substitution, reaching a maximum size at the interior region of the fracture surface. The samples doped Pb sintered 860°C showed
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needle-like structure between the flake-like grains that happened when (2223-Bi) doped with Pb to increase the weak link between grains that explain the decrease in resistivity of such samples.

4-Conclusions

In this paper a systematic study on the (Bi2Sr2Ca2Cu3O10+x, (Bi2−xPbxSr2Ca2Cu3O10+x) for x=0.1, 0.35, 0.4) and (Bi2−xAlxSr2Ca2Cu3O10+x for x=0.1, 0.2, 0.8)) HTSC prepared by solid state reaction method is presented. The Bi-Sr-Ca-Cu-O system consist of two phase(low Tc and high Tc phases)related to 2212 and 2223 phases. The Pb substitution of Bi-Sr-Ca-Cu-O system increases the volume fraction of high Tc phase(2223) and we seen the increase of Pb concentration increases the value of Tc, but when doped Al with the (Bi-Sr-Ca-Cu-O) the best value of Tc when the x=0.8 but smallest value when x=0.2. The X-ray diffraction analysis of all samples showed orthorhombic structure. An increase in b-axis from 5.346 Å to 5.679Å play an important role to increase Tc of 2223-Bi system. Appearance of texture in SEM images for all samples under study such as plate-like or flake-like accompanies the formation of superconducting phase.

<table>
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<tr>
<th>Samples</th>
<th>δ (Oxygen Content)</th>
<th>Tc(°K)onset</th>
<th>Tc(°K)Offset</th>
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<tbody>
<tr>
<td>Bi2−0.5Sr2−0.5Ca2−0.5Cu3−0.5O10+x</td>
<td>0.518</td>
<td>110-90</td>
<td>80</td>
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<tr>
<td>Bi1.65Pb0.35Sr2Ca2Cu3O10+x</td>
<td>0.683</td>
<td>112</td>
<td>100</td>
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<tr>
<td>Bi1.65Pb0.35Sr2−0.5Ca1−0.5Cu3−0.5O10+x</td>
<td>0.511</td>
<td>120</td>
<td>100</td>
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<tr>
<td>Bi1.65Pb0.35Sr2−0.5Ca1−0.5Cu3−0.5O10+x</td>
<td>0.781</td>
<td>125</td>
<td>105</td>
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<tr>
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<td>0.192</td>
<td>90</td>
<td>50</td>
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<tr>
<td>Bi2−0.5Al0.5Sr2Ca2Cu3O10+x</td>
<td>0.421</td>
<td>120</td>
<td>80</td>
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<tr>
<td>Bi2−0.5Al0.5Sr2−0.5Ca1−0.5Cu3−0.5O10+x</td>
<td>0.329</td>
<td>115</td>
<td>60</td>
</tr>
</tbody>
</table>
Figure (1): The x-ray diffraction for the compound

\[ (\text{Bi}_2\text{-Sr}_2\text{-}\text{Ca}_2\text{-Cu}_3\text{O}_{10+\delta}) \]

Figure (2): X-ray diffraction pattern for the compound

1-\((\text{Bi}_{1.9}\text{Pb}_{0.1}\text{-Sr}_2\text{-Ca}_2\text{-Cu}_3\text{O}_{10+\delta})\), 2-\((\text{Bi}_2\text{-Sr}_2\text{-Ca}_2\text{-Cu}_3\text{O}_{10+\delta})\)
The influence of Pb, Al doped on the high-temperature superconductor (Bi:2-Sr2-Ca2-Cu3-O10+n).

Figure (3): X-ray diffraction pattern for the compound
1- (Bi_{1.85-Pb_{0.35-Sr2-Ca2-Cu3-O10+n}}, 2- (Bi_{1.85-Pb_{0.35-Sr2-Ca2-Cu3-O10+n}})

Δ Impurity
L Low phase
H High phase

Figure (4): The X-ray diffraction for the compound
1- (Bi_{2-Sr2-Ca2-Cu3-O10+n}), 2- (Bi_{2-Al_{0.1-Sr2-Ca2-Cu3-O10+n}})
Figure (5): The X-ray diffraction for the compound

1-(Bi2-Al22-Sr2-Ca2-Cu2-O_{10.6}), 2-(Bi2-Al22-Sr2-Ca2-Cu2-O_{10.6})

* Impurity
L Low phase
H High phase
The influence of Pd Al doped on the high-temperature superconductor \( \text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x} \).\(^{51}\)

![Graph showing resistivity versus temperature for HTSC Bi$_2$Sr$_2$Ca$_2$Cu$_3$O$_{10+x}$](image)

**Figure (6)**: The resistivity versus temperature for HTSC

\[ \text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x} \]
Figure (7): The resistivity versus temperature for HTSC

$\text{Bi}_{2+x}\text{Pb}_x\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10.5}$
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- Bi2-Al0.1-Sr2-Ca2-Cu3-O4+6
- Bi2-Al0.2-Sr2-Ca2-Cu3-O10+6
- Bi2-Al0.4-Sr2-Ca2-Cu3-O10+6

[Graph showing resistivity vs. temperature for HTSC Bi2-Alx-Sr2-Ca2-Cu3-O10+x]

Figure (8) : The resistivity versus temperature for HTSC

Bi2-Alx-Sr2-Ca2-Cu3-O10+x
Figure (9) morphology of fracture surface of compound Bi₂Sr₂Ca₂Cu₃O₁₀±δ

Figure (10) morphology of fracture surface of compounds (1- (Bi₂Pb₄Sr₂Ca₂Cu₂O₁₀±δ), 2- (Bi₄Sr₂Pb₁Sr₂Ca₂Cu₂O₁₀±δ), 3- (Bi₄Pb₉Sr₂Ca₂Cu₂O₁₀±δ))
The influence of Pb Al doped on the high-temperature superconductor (Bi2Sr2Ca2Cu3O10+δ).

Figure 11: Morphology of fracture surface of compound Bi-Al-Sr-Ca-Cu-O_{10.5}.

Figure 12: Morphology of fracture surface of compound Bi-Al-Sr-Ca-Cu-O_{10.5}.

Figure 13: Morphology of fracture surface of compound Bi-Al-Sr-Ca-Cu-O_{10.5}.
References


تم تحضير مركبات من Bi-Sr-Ca-O (Pb) طريقة تفاعل الحالة الصلبة في تحضير النماذج، ثم طمعت هذه المركبات بالرصاص (Bi2xPb1-xSr2CaCu3O10+y) عند قيم (x=0.1, 0.35, 0.4) وكذلك المركبات AlxAl2+Sr2CaCu3O10+y عند قيم (x=0.1, 0.2, 0.8). لقد تم الحصول على طور التوصيل الفائق باستخدام درجة حرارة تدريجية 860 درجة مئوية لمدة 16 ساعة بالتعانق، وان معدل التبريد البطيء البالغ (1°C/min) تلعب دوراً مهماً في عملية تشكيل طور التوصيل الفائق لمركبات الزمثون متعددة الأطوار. إن التركيب البلوري لمركبات الزمثون الفائق التوصيل المستقرة حراريا تكون معيث قائمة (Orthorhombic) ذات ثوابت ديكاتية (a=5.394Å, b=5.346Å, c=30.753Å) للطور الواضح في حين قيمة (Te) Aº.

للطور العالي، اعتمدت طريقة قياس النقاوة الكهربائية لإيجاد قيم درجات الحرارة الحرة (Te). لهذه النماذج وذلك باستخدام وظيفة تيريد تعمل بالنتروجين السائل وكانت أعلى قيمة عند (x=0.4) للنماذج الطامحة بالرصاص حيث كانت قيمة درجة الحرارة الحرة تزداد بازدياد قيم (x). بينما كانت أعلى قيمة لدرجات الحرارة الحرة (Te) للنماذج المطثمة بالألنيون عند قيمة (x=0.8). تم فحص النماذج باستخدام الجهاز الإلكتروني الماسي (SEM) وأظهرت الصور تكوين طور صافائح والطور الواقعي (flake). في نماذج التوصيل الفائق.