Partial substitution effects on structure & electrical properties of high temperature Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductors

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Abstract:

The partial substitution effect of Tl,sr on the structure & electrical properties of high temperature Bi_{2-x} Tlx Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ super conductor have been studied these compounds have been prepared using the solid state reaction method, have been investigated where x=o, 0.05, 0.1, 0.2 & y=0, 0.1, 0.2, 0.3

X-ray diffraction showed that the structure with tetragonal phase with a=b=5.43A^0, C=34.18A^0 with Tc=123K. where x=0, y=0, but where x=0.05, y=0, the structure remains tetragonal with increasing in c-parameters to 34.81A^0 with Tc=128K, on the other hand, when x=0.1, 0.2 the structure has been found that the orthorhombic structure with Tc=100K.[9]

It is observed that the system with Y=0.1, 0.2, 0.3 the structure remained as it was and the critical temperature decreased from 123K to 110K.

By substituting x and y together, the best structure was at x=0.05, y=0.1 with increasing in critical temperature from 123K to 140K due to increasing in the volume of lattice or by intergowths of a large number of Cu-O layer in the cell that leads to raise [7,8] Tc.

Introduction:

The discovery of superconductivity between 7K and 22K in Bi-Sr-Cu-O compound has been reported by Michel et al 1987[1]. Sheng and Hermann [2] discovery of high temperature in the Tl-Ba-Cu-O system was initially overshadowed by the break throughs in the Bi-Ca-Sr-Cu-O system.

Sabah et al (1998)[3] were found that Pr substitution in high temperature Tl-Ba-(Ca, Pr)-Cu-O superconductor, and explained that the increasing the relation of Pr in the compound to 0.3 will increase the ratio of oxygen which affect on the concentration of the charge carrier.

Mohamad et al (2002) [4] were studied the effect of Hg effects as a partial substitution for Tl_{2223} compounds.

The effect of partial substitution of Tl & Sr on the structure & electrical properties are investigated in this paper on the high temperature Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductors.

Experimental:

The high temperature Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductors samples were prepared from the starting of high purity material of Bi_2O_3, Tl_2O_3, B_aCO_3, $CaCO_3$, $Sr(NO_3)_2$ and CuO with molar ratio of 2:2:2:3 due to the atomic weight.[11,8]

The high purity powder is well mixed and loaded in alumina crucible which is then placed in furnace. It is annealed to 850^0 for 20hr then cooled down in air at room temperature for 25hr.

The powder were pressed into 1gm pellets approximately 12mm in diameter and 1.8mm thick. These pressed pellets were sintered in oxygen at 850 C^0 for 30hr with double annealing, then the pellets were slowly cooled down to room temperature.[10]

The critical temperature (Tc) was determined from the changing of electrical resistivity with temperature by using four-probe technique.

The oxygen content in the sample were measured by using iodometric titration method.

Details of experimental work for determination of (Tc) and oxygen content is published in [ref 5].

X-ray diffraction patterns of these samples at room temperature were obtained using Phillips X-ray diffractometer with CuKα source and 1.5418 A^0 wavelength.

Results & Discussion:-

The structure of high temperature Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductor showed by X-ray analysis of the prepared samples at 850^{0}C.

Fig(1) shows the existence of single tetragonal phase with lattice a=b=5.43A^0 and c=34.13A^0 where x=0, y=0, by using a computer program written in Basic to find the value of the lattice parameters. Table I shows the values of lattice parameters, but by partial substituting Tl with Bi as x=0.05, 0.1, 0.2, the structure remains tetragonal phase with increasing in c parameter to 34.81A^0 where x=0.05, on the other hand, when x=0.1, 0.2, the structure has been attributed to the change in structure from tetragonal to orthorhombic phase with lattice parameters a=5.42^{0}A, b=5.22^{0}A, C=30.18A^0 and the results are shown in Fig(2).

The structure of the system at y=0.1, 0.2, 0.3 remained as it was (tetragonal phase) as y=0, with lattice parameters a=b=5.44^{0}A c=34.18A^0, as shown in Fig(3), it was noticed that the original peaks stayed as they were with small shift, so it affected on the lattice constant (c) such that it became smaller thus the volume of the lattice became smaller that could explain the reason behind the decrease in Tc.

By substitution both x and y in a systematic way, such that each value x=0.05, 0.1, 0.2 is taken with the three values y=0.1, 0.2, 0.3 as shown in fig(4).

The sample where x=0.05, y=0.1 shown the tetragonal of phase new peak appeared as impurities i.e CuO, but at x=0.05, y=0.2, 0.3 shows the orthorhombic phase with new peaks appeared which inferred the formation of new structure of CuO and SrO.

While the changes in the structure occurred in x more than 0.05, this means the best substitution which give the best structure was x=0.05, y=0.1.

The relation between the resistivity and the temperature is shown in fig(5). Values of critical temperature (Tc) have been determined from sudden drop in electrical resistivity, these values are shows in table II.

The critical temperature is increasing from 123 to 128 when x varies from 0 to 0.05, when x=0.1 the (Tc) starts to decrease apparently.

The increase in Tc means that it increase the mobility in the b-direction of Cu-O plane leading to a higher Tc. Similar results were obtained ref(4) in different compound as Tl_{2223} system.

It is possible to notice that the physical interpretation of this change according to change in carrier density and depend on increasing in oxygen content.

While when y=0.1, 0.2, 0.3, the critical temperature decrease from 128K to 110K as shown in fig(6).

The decreasing in (Tc) value has been attributed to the change in structure from tetragonal to orthorhombic phase.

By substituting x & y together as shown in fig (7) the best value of Tc was 140K at x=0.05, y=0.1, the increasing in Tc related with the increasing in oxygen content stoichiometry which affect on the electronic behavior by shifting the Fermi level, the same results were obtained by[5].

Conclusion:-

1. Superconductivity is shown to be possible in the tetragonal and orthorhombic phase, according to c-parameter.
2. The best structure & Tc was at x=0.05, y=0.1 depends on increasing of the oxygen content.
3. Double annealing method is the best method to increasing the Tc and causes in decreasing the structure defect.
4. The increasing in Tc value related with partial substitution leads to increasing in oxygen content which affect on the electronic structure by shifting the Fermi level.

Table I
Lattice parameters of high temperature
Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductor

Sample	Lattice Parameters		
	a (A°)	B (A°)	c (A°)
Bi_2 Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	5.43	5.43	34.13
$Bi_{1.95}$ $Ti_{0.05}$ Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	5.43	5.43	34.81
$Bi_{1.9}$ $Ti_{0.2}$ Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	5.42	5.42	30.18
$Bi_{1.8}$ $Ti_{0.2}$ Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	5.40	5.21	30.13
Bi_2 $Ba_{1.9}$ $Sr_{0.1}$ Ca_2 Cu_3 $O_{10+\delta}$	5.44	5.44	34.72
Bi_2 $Ba_{1.8}$ $Sr_{0.2}$ Ca_2 Cu_3 $O_{10+\delta}$	5.411	5.411	30.18
Bi_2 $Ba_{1.7}$ $Sr_{0.3}$ Ca_2 Cu_3 $O_{10+\delta}$	5.411	5.411	30.01
$Bi_{1.95}$ $Ti_{0.05}$ $Ba_{1.9}$ $Sr_{0.1}$ Ca_2 Cu_3 $O_{10+\delta}$	5.46	5.46	34.88
$Bi_{1.9}$ $Ti_{0.1}$ $Ba_{1.9}$ $Sr_{0.2}$ Ca_2 Cu_3 $O_{10+\delta}$	5.28	5.22	31.18
$Bi_{1.8}$ $Ti_{0.2}$ $Ba_{1.7}$ Sr0.3 Ca_2 Cu_3 $O_{10+\delta}$	5.18	5.26	30.18

Table II
Critical temperature for examined
Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductor with oxygen content

Sample	Critical temperature Tc(K)	Oxygen content $_{10+\delta}$
Bi_2 Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	123	10.22
$Bi_{1.95}$ $Ti_{0.05}$ Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	128	10.28
$Bi_{1.9}$ $Ti_{0.2}$ Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	108	10.21
$Bi_{1.8}$ $Ti_{0.2}$ Ba_2 Ca_2 Cu_3 $O_{10+\delta}$	100	10.18
Bi_2 $Ba_{1.9}$ $Sr_{0.1}$ Ca_2 Cu_3 $O_{10+\delta}$	125	10.26
Bi_2 $Ba_{1.8}$ $Sr_{0.2}$ Ca_2 Cu_3 $O_{10+\delta}$	120	10.18
Bi_2 $Ba_{1.7}$ $Sr_{0.3}$ Ca_2 Cu_3 $O_{10+\delta}$	110K	10.14
$Bi_{1.95}$ $Ti_{0.05}$ $Ba_{1.9}$ $Sr_{0.1}$ Ca_2 Cu_3 $O_{10+\delta}$	140	10.38
$Bi_{1.9}$ $Ti_{0.1}$ $Ba_{1.9}$ $Sr_{0.2}$ Ca_2 Cu_3 $O_{10+\delta}$	112	10.26
$Bi_{1.8}$ $Ti_{0.2}$ $Ba_{1.7}$ Sr0.3 Ca_2 Cu_3 $O_{10+\delta}$	95	10.21

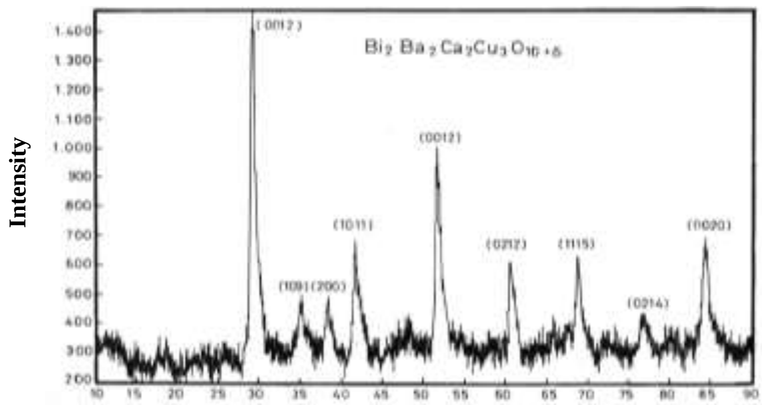

Fig (1) : X – ray diffraction pattern of high temperature
Bi_2 Ba_2 Ca_2 Cu_3 $O_{10+\delta}$ superconductors

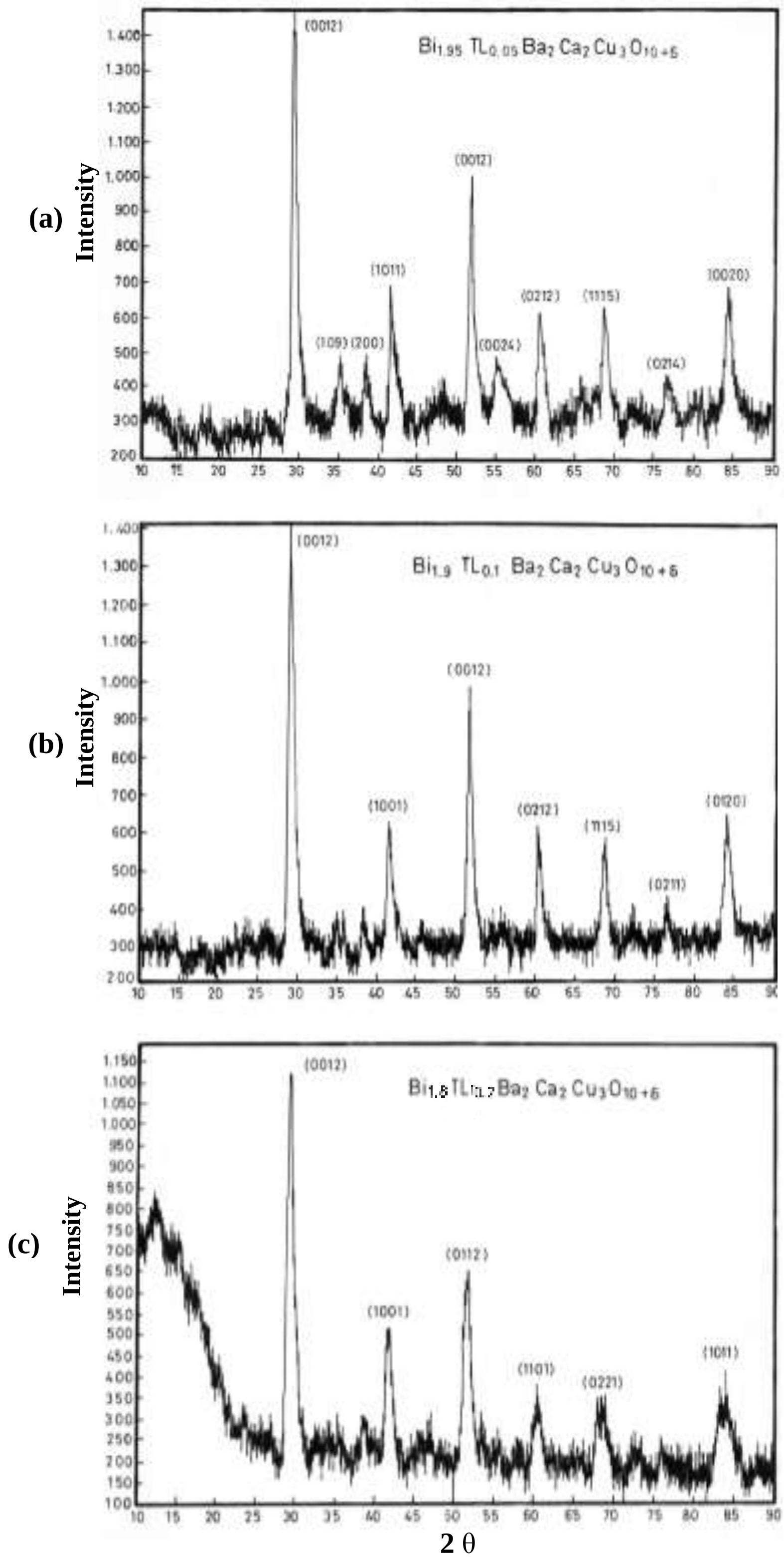

Fig (2) : X – ray diffraction pattern of high temperature Bi_{2-x} Tl_x Ba_2 Ca_2 Cu_3 $O_{10+\delta}$ superconductors at a. x = 0.05, b. x = 0.1, c. x = 0.2

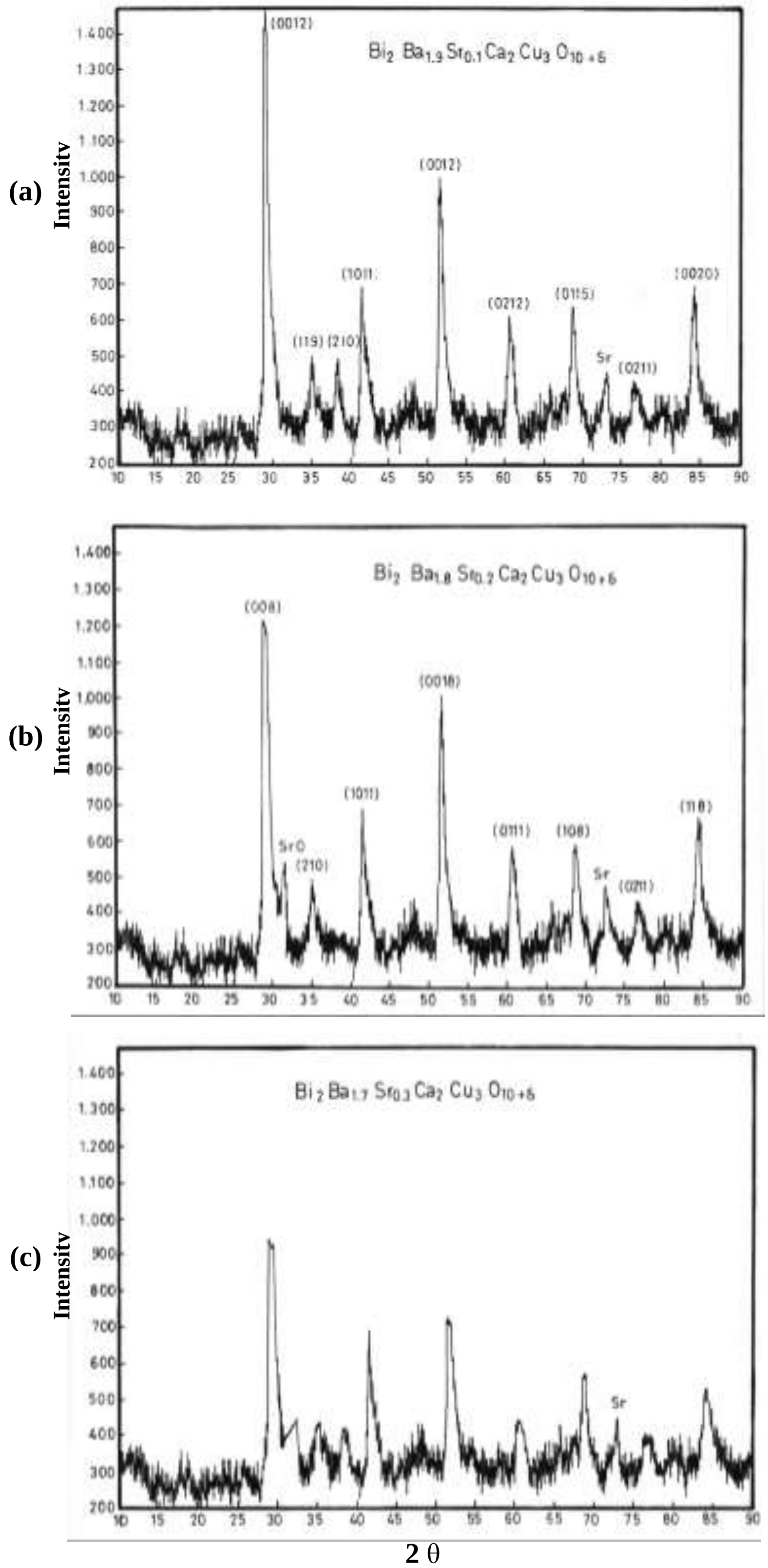

Fig (3) : X – ray diffraction pattern of high temperature
$Bi_2\,Ba_{2-y}\,Sr_yCa_2\,Cu_3\,O_{10+\delta}$ superconductors
at a. y = 0.1, b. y = 0.2, c. y = 0.3

(a)

(a)

(a)

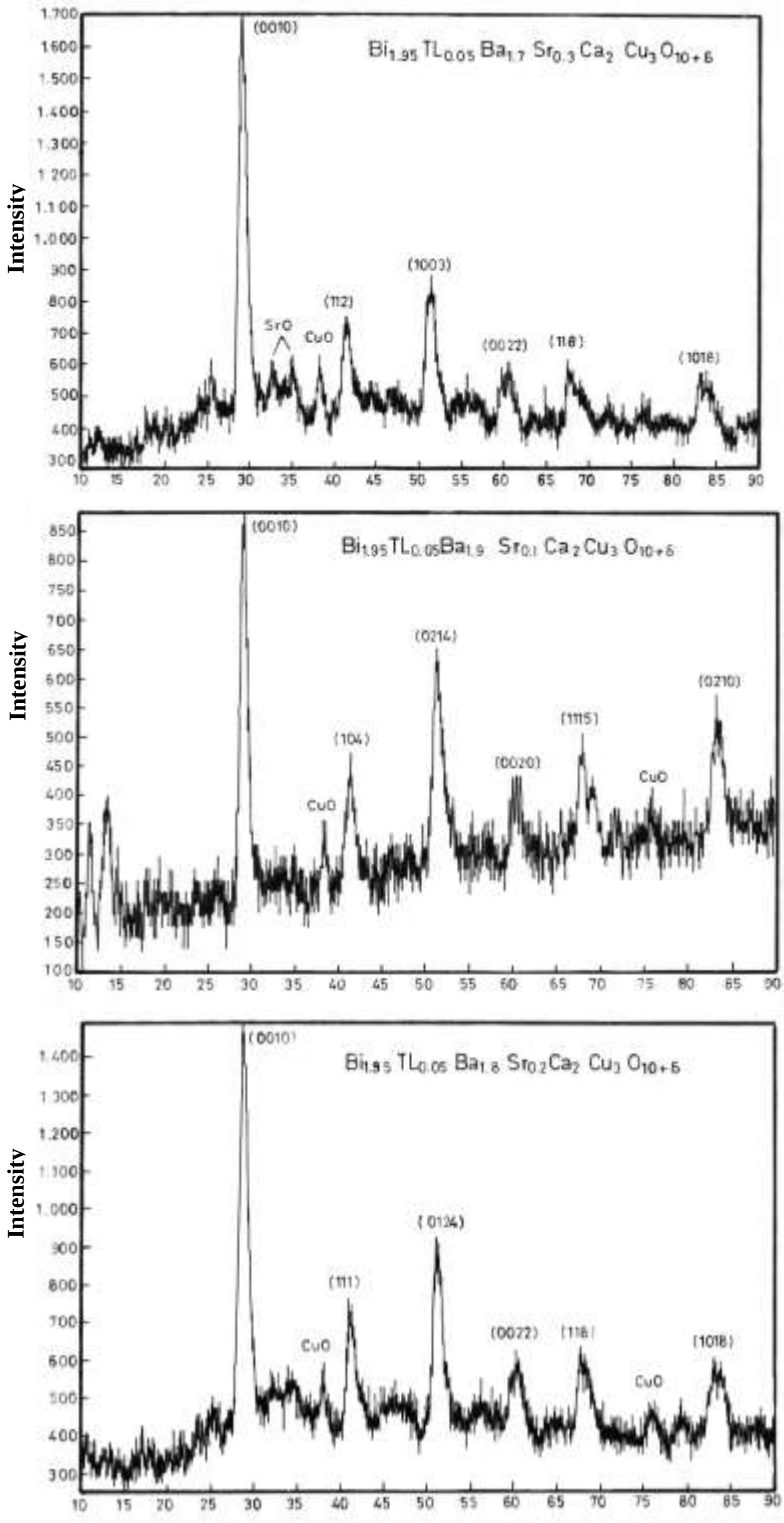

Fig (4) : X – ray diffraction pattern of high temperature
Bi_{2-x} Tl_x Ba_{2-y} Sr_yCa_2 Cu_3 $O_{10+\delta}$ superconductors
at a. x = 0.05, y = 0.1, b. x = 0.05, y = 0.2, c. x = 0.05, y = 0.3

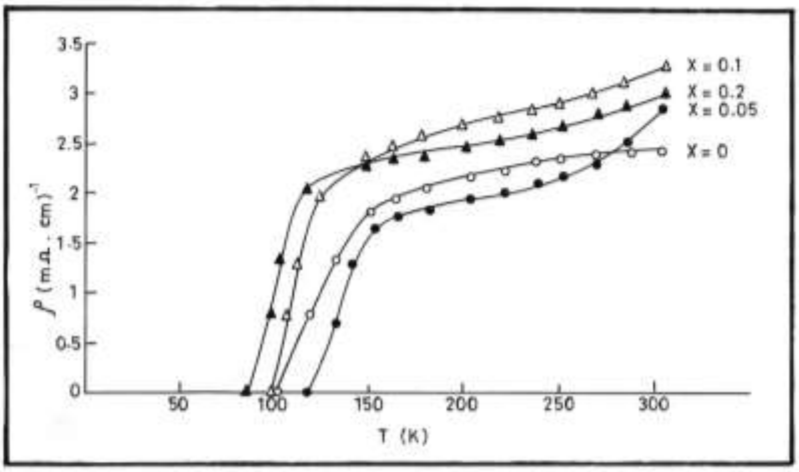

Fig (5) : The resistively versus temperature for high temperature Bi_{2-x} Tl_x Ba_2 Ca_2 Cu_3 $O_{10+\delta}$ superconductors at x = 0 , 0.05 , 0.1 , 0.2

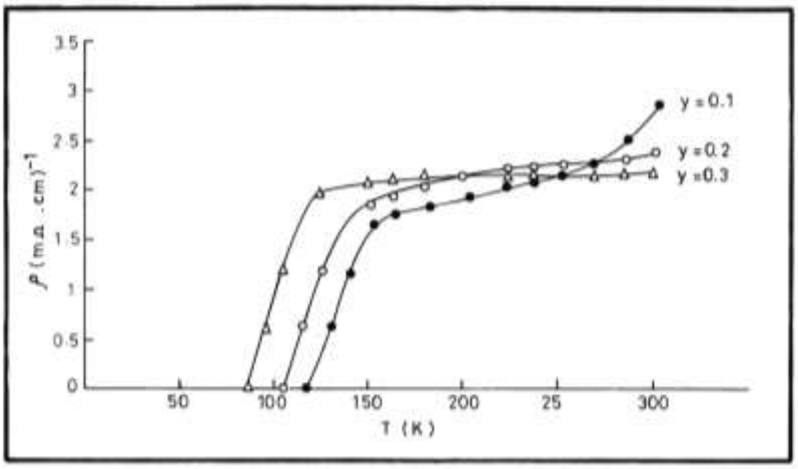

Fig (6) : The resistively versus temperature for high temperature Bi_2 Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductors at y = 0.1 , 0.2 , 0.3

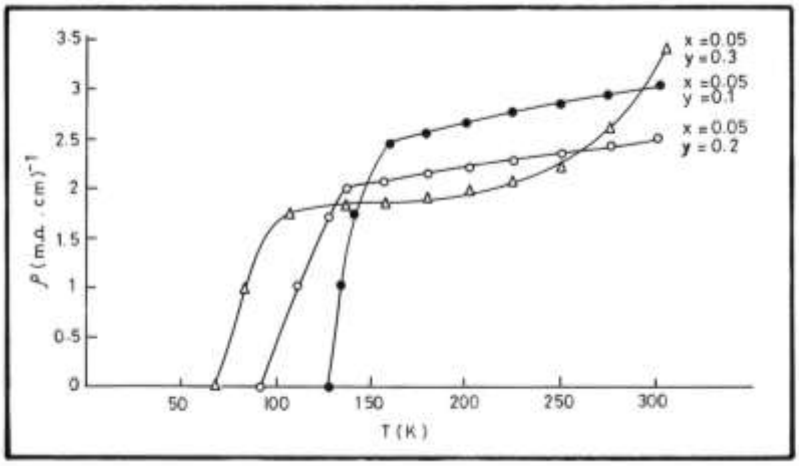

Fig (7) : The resistively versus temperature for high temperature Bi_{2-x} Tl_x Ba_{2-y} Sr_y Ca_2 Cu_3 $O_{10+\delta}$ superconductors at x = 0.05 , y = 0.1, 0.2 , 0.3

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تأثير التعويض الجزئي على الخصائص التركيبية والكهربائية للمركب $Bi_{2-x}Tl_xBa_{2-y}Sr_yCa_2Cu_3O_{10+\delta}$ الفائق التوصيل عند درجات الحرارة العالية

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الخلاصة:

تم في هذا البحث دراسة تاثير التعويض الجزئي للعناصر Tl,Sr على الخواص التركيبة والكهربائية للمركب : (BI2-xTlxBi2-ySryCa2Cu3O10+δ) الفائق للتوصيل الكهربائي عند درجات الحرارة العالية والمحضره بطريقة تفاعل الحالة الصلبة حيث تمت هذه الدراسة تحت درجة حرارة تلدين850 c وضغط هايدروستاتيكي 9 طن \اسم ٢ وعندما كانت نسبة التعويض ل(x) وتساوي X=0,0.05,0.1,0.2 و Y=0,0.1,0.2,0.5 لقد أظهرت الدراسة نتائج الحيود للأشعة السينية بان التركيب البلوري من النوع الرباعي القائم (tetragonal) مع الزيادة في الطول المحور (c) كانت أبعاد الشبيكه a=b= 5.43 A c=34.18A, عندما كانت نسبة التعويض X=0,Y=0 ودرجة الحرارة الحرجة للمركب وتساوي Tc=123k ولكن عند نسبة التعويض ل x=0.05,y=o بقي التركيب البلوري محافظا على صيغته مع تحسين للمركب وزيادة طول المحور (c)إلى c=34.81 A وزيادة درجة الحرارة الحرجة الى Tc=128k وعند زيادة نسبة التعريف x=0.1,0.2 انخفضت درجة الحرارة الحرجة إلى 100k وعند دراسة تأثير نسبة التعويض (y) الى المركب وبنسب y =0.1,0,..3 لاحظنا لكثير في التركيب البلوري وانخفاض في درجة الحرارة الحرجة من 123k.الى 110K وعند نسبة التعويض الجزئي ل (x,y) في ان واحد حصلنا على أفضل خصائص للمركب ودرجة الحرارة الحرجة عندما كانت نسبة التعويض x=0,050 y0,1 حيث بينت نتائج دراسة حيود الأشعة أظهره بآن أبعاد الشبيكة البلورية ازدادت بصورة واضحة وبزيادة طول المحور c C=36.88A , a=b=5,46A وازدادت درجة الحرارة الحرجة من 123,k إلى 140K حيث ظهرت قيما جديدة وعند البحث عنها وجدنا بأنها قيم لاوكسيد النحاس .الذي له الدور الأساسي في عملية التوصيل الكهربائي الفائق وكذلك اخذ المركب دور الكمال في التركيب البلوري .