Superconducting Compound Hg0.8Sb0.2Ba2Ca2Cu3O8+δ Compared with Hg0.8Sb0.2Ba2Ca1Cu2O6+δ to Evaluate Transition Temperature

Abbas K. Saadon[1*], Kareem A. Jasim[2], Auday H. Shaban[3]

Abstract

The high temperature superconductor's compounds are one of the hot spot field of science, due to their applications in industries. Hg0.8Sb0.2Ba2Ca2Cu3O8+δ and Hg0.8Sb0.2Ba2Ca1Cu2O6+δ, were manufactured using a doable-step of solid state reaction method. The samples were sintered at 800 ° C. The transition temperatures Tc are found from electrically resistively by using four probe techniques. The resistivity become zero when the transition temperature Tc(offset) have 131 and 119 K, and the onset temperature Tc(onset) have 139 K for Hg0.8Sb0.2Ba2Ca2Cu3O8+δ and 132 K for Hg0.8Sb0.2Ba2Ca1Cu2O6+δ. Analysis of X-ray diffraction showed a tetragonal structure with lattice parameters changes for all samples.

Key Words: Transition Temperature, Superconducting Compound, Mercury-based.

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Introduction

The aim of each researcher in the field of superconductors is to manufacture room temperature superconductor materials. The researchers are trying to improve the properties of the superconductors to rise the transition temperature (T_c). The main advantage of rising (T_c) is to reduce the power loss when transiting the power through conducting cables.

The superconducting mercury-based $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ (n=1, 2, 3----8 ,n is Cu-O layers) are widly investigated by specilists due to their high (T_c) that shown by the series (Hg-1201), n=1, has (T_c) of 94K, (Hg-1212) has T_c=127 K and n=3, (Hg-1223), has T_c = 135 K [1, 2]. Where the transition temperature was increased to 150-160 under high pressure [3]. All phases of the upper phase of mercury-base crystallize with a quadratic cell structure and perovskite layers [4].

The Mercury - based superconductor structure is almost the same as the TL and Cu - base superstructures with a single layer of Tl-O, but the main difference is the very low oxygen vacancies of the Tl-O layers, while oxygen vacancy loss is higher in Hg-O layers.

Corresponding author: Abbas K. Saadon
Address: [1*]Department of Physics, College of Education for Pure Sciences (Ibn Al Haitham), University of Baghdad, Baghdad, Iraq; [2]Department of Physics, College of Education for Pure Sciences (Ibn Al Haitham), University of Baghdad, Baghdad, Iraq; [3]College of Science, University of Baghdad, Baghdad, Iraq.
[2]E-mail: kaj_1964@yahoo.com
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Oxygen atoms are very slightly associated with mercury, and their occupancy rates are likely to vary widely depending on the preparation; they have shown that there are different numbers of homologous mercury series. Where Cu-O2 planes are responsible for superconductivity of high temperatures [5-7].
The stability of the phase, in particular, carbon dioxide presence and moisture, is still having problems. Several reports show that Hg-1223 is supplemented by positive substitutions for Chemical elements for high phase formation and superconductivity.
In doping with high equivalence type, Pb or other elements, the current of critical density and phase formation of Hg-1223 can be improved [8-9-12].
In this work, we will study the electrical and structural characteristics to evaluate transition temperature of the two superconductors $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ and $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$. that have been manufactured in optimal conditions.

Experimental

The manufacturing process and the rates of the compound's elements are the guide in this research. There many methods for preparation of the superconducting samples. The solid state reaction method was used in this research to fabricate the samples.
$Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ and $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$ phases of the superconductors were prepared through applying the solid-state reaction method. The raw materials powders with purity (99.998% of might & Baker LTD Dagenham England) with the right weights were mixed with respect to the general formula starting by HgO, Sb2O3, BaO, CaO and CuO materials:

$$0.8HgO + 0.1Sb_2O_3 + 2\,BaO + 2\,CaO + 3CuO \rightarrow Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta} \quad (1)$$

And

$$0.8HgO + 0.1Sb_2O_3 + 2\,BaO + CaO + 2CuO \rightarrow Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{8+\delta} \quad (2)$$

The sensitive balance that been used to weights the mixture powders has an accurate reading: 0.001. *The* full capacity of the balance is 110 g, and manufactured type is (Mettler H35 AR). Sampling powders were collected through the two step precursor-method.
Firstly, the three components powder (BaO, CaO, with CuO) set at the agate mortars to be mixed; an adequate amount of propane to obtain a homogeneous mixture and clay formation and the grinding process continued for about 30 - 50 minutes. The drying of the mixture in an oven at a temperature (523K). The programmable oven was used to heat the blend until 1073 K for 3 hours (100 K / h). The cooling process was applied to the powder to reach room temperature at with same rate.
Secondly, the precursor $Ba_2Ca_2Cu_3O_7$ was mixed with Sb_2O_3 and HgO in order to obtain the basic compositions of the compound $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ and $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$. The powder was pressed under a hydraulic pressure below the pressure of 7 ton / m^2 in the form of pellets using a mold with diameter (1.2 cm) and the thickness between (0.2 – 0.3 cm). The pellets were sintered on (1128 - 1133) K for 24 hours at 100 ^{0}C / hour. The decreasing of temperature to reach room temperature will be at the same rate. "Standard probe technique" was utilized for investigating the $T_c$of the samples. The resistivity was investigated with respect to temperature changes. The steps of this approach, described in reference [13}. 15
X-ray spectrum illustrated the structure of the prepared sample. (Philips) current $Cu_{k\alpha}$ current (20 mA), voltage (40 KV)and λ=1.5405 A^0. The calculations for lattice parameters "a, b, c" were achieved by programming Cohen method, least square (14, 15).

Results and Discussion

Fig. 1, illustrated the r resistivity (ρ) of sample $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+}$ (1212 phase) through the range of temperature (77 to 300) K. It is observed through this form that the electrical resistivity (ρ) behaves with metal behaviour and it decreases with decreasing the temperature. It also notes that this decrease in resistivity (ρ) becomes almost acute when the temperature is 132 Kelvin and then became zero at the temperature of 119 K. This indicates that the sample has shifted from the normal state to superconductor state, The width of its transformation (ΔT_c) is approximately 13 K, While the sample $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ (1223 phase) possesses the same metallic behavior but the critical temperature $T_{c(on)}$ shows at a temperature of 139 K shrouds where the electrical resistivity starts with extreme gradation and then the critical temperature $T_{c(off)}$ becomes zero at 131 K. The width of the transition temperature ΔT_c is equal to 8 Kelvin. Obviously, these samples also show a small scale in the width of the transition temperature (ΔT_c), which tend to decrease in one or more of the following reasons:

- Concentration of impurities.
- Non-superconducting areas.
- Multiple phases superconducting stages in samples

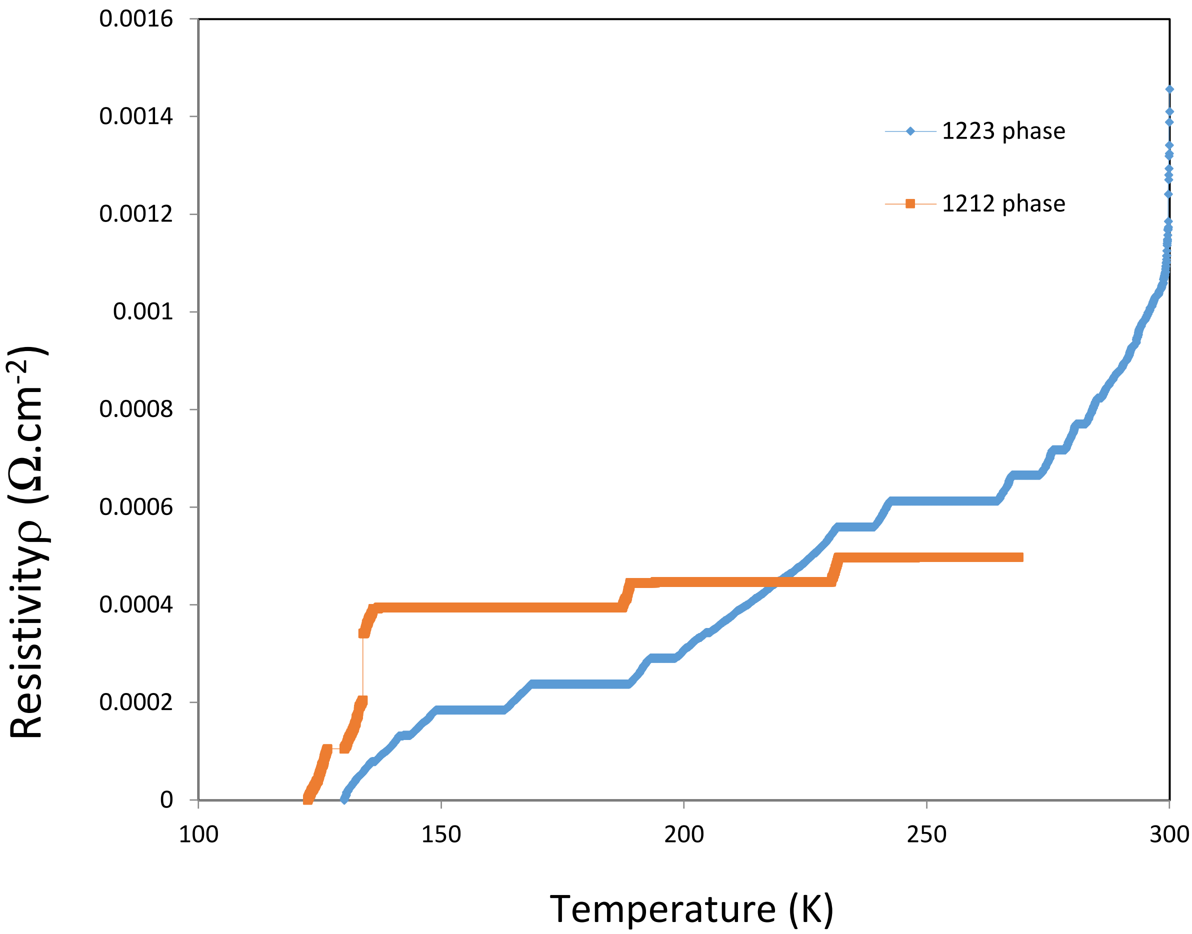

Figure 1. Resistivity as function of Temperature for $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ and $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$

X-ray diffraction data illustrated the samples have nearly two phases were formed Hg-1212 and Hg-1223. The figure shows that the blue curve, which represents the $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ phase (1223) contains a number of high and low (1212 and 1201) phases and some of the impurities (Ca_3HgO_6 and Ca_2CuO_3). As well as note through the red curve, which represents the $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$phase (1212) contains a number of Low phase and some of the impurities.

When comparing these two curves we note that the volume fraction of the phase 1223 Larger than the phase (1212), this is the reason for the increase in transition temperature. The reason for the existence of more than two phases can be linked to how the stacking along the axis, because the disintegration of stage 1212 may lead to the introduction of the layer Cu-O between layers, leading to increase the ratio of phase 1223.

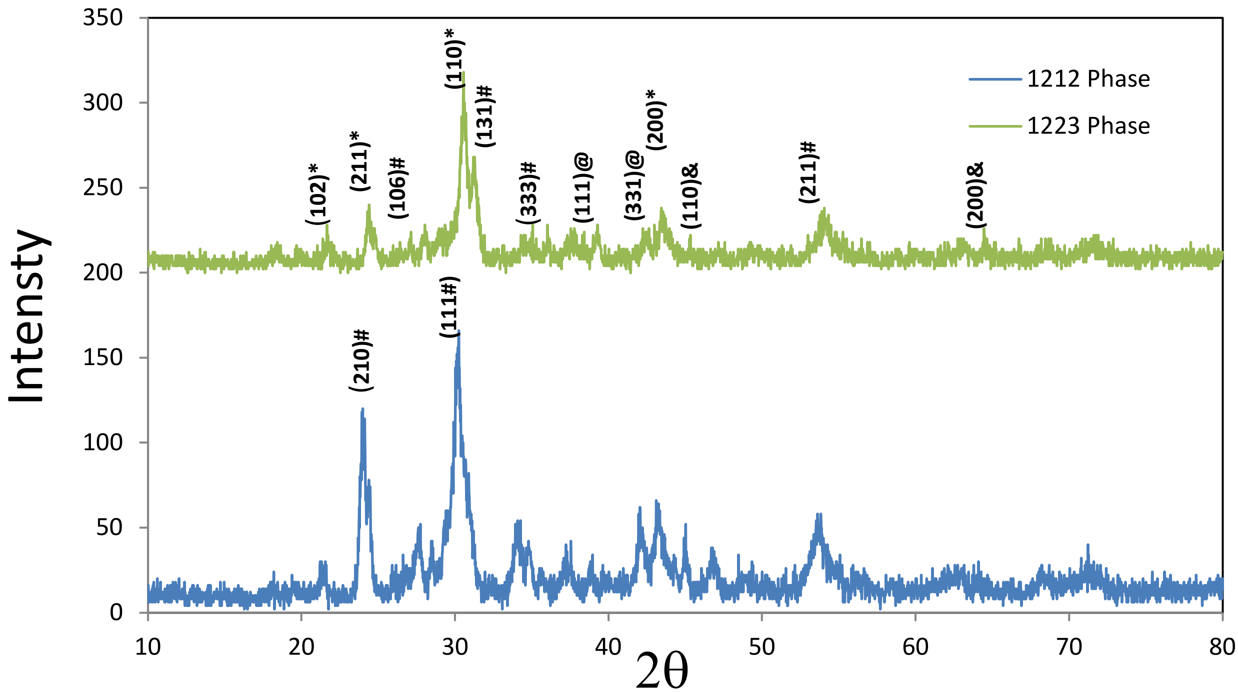

Figure 2. X-ray spectrum for $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$(*), $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$(#) and a small amount of Ca_3HgO_6 (@) and Ca_2CuO_3(&)

Table (1) shows the transition temperature, lattice parameters a, b, c/a, ρ_m and V_{phase} for all samples. It was seen from this table that all transition temperature, lattice parameters, Mass density ρ_m and volume fraction (V_{phase}) changing with increasing Cu-O layer. The formation of the Hg-1223 phase (volume fraction 77.91%) was observed in the sample $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$, while rom the sample $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$ we getting the high phase Hg-1212 (volume fraction 80.53%).

Table 1. Transition temperature, lattice structure parameter a, b, c, c/a, Volume fraction V_{phase} and mass density ρ_M for $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ and $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$ superconductors

samples	$T_{c(OFF)}$ K	$T_{c(On)}$ K	*a* A⁰	*b* A⁰	*c* A⁰	*C/a*	ρ_m (g/cm³)	V_{Phase}
$Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$	119	132	3.847	3.846	15.79	4.145	5.833	80.53
$Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$	131	139	3.842	3.8425	12.66	4.147	5.752	77.91

Conclusions

In this study, we examined the comparison of the superconducting properties of $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ and $Hg_{0.8}Sb_{0.2}Ba_2Ca_1Cu_2O_{6+\delta}$. it was seen these samples are in mainly phases of Hg-1212 and Hg-1223.These two samples were found sensitive to the Cu - O layer. It was found that all transition temperature and structural characteristics changing with increasing Cu-O layer. The higher T_c for both compounds are the best structure will be, because this research are investigating the best high temperature superconductor. The maximum transition temperatures $T_{c(offset)}$-131 K and $T_{c(onset)}$-139k are found from $Hg_{0.8}Sb_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ phase.

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