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Article

Studying Some Physical Properties Of The Superconducting Compound

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Abstract: The current research focuses on the effect of partial substitution of yttrium nanoparticles for barium on the electrical and structural properties of the superconducting compound Bi2Ba2-yYyCa2Cu3O10+, where y = 0, 0.1, 0.2, 0.3, and the samples were prepared using the solid state reaction (SSR) method. The samples were subjected to heat treatment in normal air for 48 hours at 800°C at a heating rate of 10°C/min. X-ray diffraction studies were performed on four materials with deferent yttrium concentrations. The results of X-ray diffraction showed that all samples had a crystal structure with differences in the lattice constants (a, b and c,)with a clear increase in the dimension c = 36.4969 Ao for the second sample when y = 0.1, there was also an increase in the proportion of the higher phase HTP%, which reached 74.76%, when it was y=0.1and the development of The formation of nano-sized granules was observed by the SEM device for the samples, and the element analysis for each sample was examined through EDS examination, as the results showed the presence of the elements and their various proportions in each sample. The critical temperature was also measured, and the results showed that the highest critical temperature is 138 K when the yttrium concentration is 0.1.

Keywords: High-temperature superconductor; Bi-2223; Yttrium nanoparticles; Solid-state reaction; Critical temperature (Tc).

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1. Introduction

One of the most significant phenomena in solid state physics is known as superconductivity. Depending on the kind of material, it is characterized as the occurrence of absence of particular resistance for a variety of metals and compounds when cooled to a given low temperature. [1]. The resistance of mercury changes with temperature decrease, and the Dutch scientist Kammer Lingh Onnes was the first to study superconductivity in 1911. When mercury is cooled to helium temperature, its resistance abruptly disappears (i.e., it is almost zero) and is almost zero thereafter. [2]. The loss of electrical resistance of particular chemical compounds when they are cooled to a specific temperature known as the critical temperature, along with the transition of these materials into a magnetic substance at that temperature, are two aspects of the phenomena of superconductivity. As a result, when cooled to a critical temperature, superconducting materials exhibit both perfect electric current conductivity and magnetic characteristics. As a result, the primary objective of scientists who specialize in the study of superconducting materials is to increase the critical temperature of these materials to room temperature so they can be employed in real-world applications and in a variety of devices without the need for intensive cooling. So, in various phases, scientists and researchers labored to create compounds of various chemical elements, such as those of yttrium (Y-Ba-CunOd), lanthanum (La-Ba-Ca-Cu d), bismuth (Bi-Ba-Can-1Cun-Od), thallium (Tl-Ba-CunOd), and mercury (Hg-Ba-Can-1Cun-Od) [1–6]. While others focused on analyzing how to produce superconducting materials and how to partially replace the components of these compounds, in order to raise the critical temperature to approach room temperature [7-10]. Also, Pb+2, Sb+2, Cr+2, and Cd+2 can be partially substituted at Tl+2 sites to enhance various features of superconductors. [8–13]. La by Ca in the bi-base and Sr by Ba in the Hg-base [14, 15].

The composition of Bi-2223 and its superconducting characteristics are improved by these substituents. In the current study, employing the solid-state reaction method, we have successfully created Bi2Ba2-yYyCa2Cu3O10+, where y = 0, 0.1, 0.2, and 0.3 polycrystalline superconductor. We investigate the structure and electrical properties of a Bi-Base superconductor produced under the conditions described. The effect of replacement on the critical temperature (Tc) is best observed.

2. Experimental

The materials were made from pure oxides in accordance with the production of the compound Bi2Ba2-yYyCa2Cu3O10, where the yttrium nanoparticle compensation ratios were y = 0,0.1,0.2, and 0.3. This included using the proper weights for powders of high purity oxides (Bi2O3, BaO, CaO, CuO, and Y2O3) where the samples were made using the SSR solid state reaction method. According to the following chemical formulas:

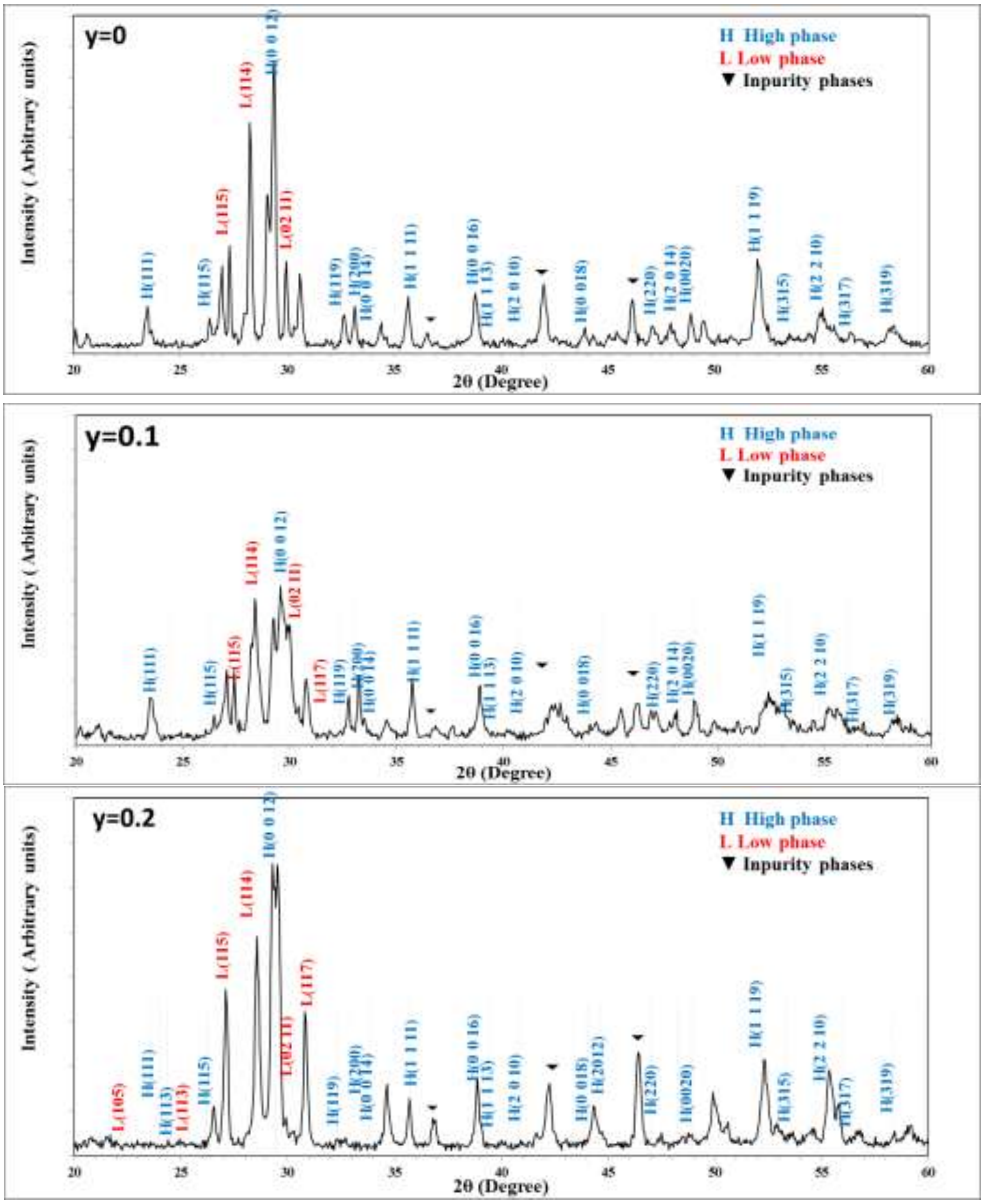
$2\ Bi_2O_3 + (2\text{-}y)\ BaO + (y)\ Y_2O_3 + 2\ CaO + 3\ CuO$ □ $Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+□}$

The powders were combined with an agate mortar, and then the powder was pressed under 8 tons of pressure for 5 minutes, resulting in discs with a diameter of 1.5 cm and a thickness varying between (0.316 - 0.284) cm. Following that, the samples were sintered in air at 800 degrees Celsius for 48 hours at a rate of Heat 10 Co/min to obtain samples and then cooled at the same rate as heating. The structural properties of the samples were investigated using a Shimadzu X-ray machine with the following specifications: $Cu_{k\alpha}$, Voltage:40 Kv, Current:30mA, Wave Length=1.5406. After obtaining the examination data, then diagnosing the phases formed in the samples and their ratios through diagnosing ((2θ, d, (hkl), I in the examination of the sample and comparing it with its counterparts in the standard examinations. As a result, the phases generated were identified (Bi 2223), and computational algorithms were used to calculate the lattice constants a, b, c, as well as the lattice coefficients per unit cell from the X-ray diagram [7] using Brack's law of diffraction. When the relationship between a, b, and c is obtained using Program X'Pert High Score Plus, the atomic dimensions of the crystal structure can be determined. An electronic scanner was utilized to examine the surface of the samples. According to the concept of electronic interaction with the material, this technology may provide images with analysis and a very high magnification of up to 100,000 times at any place on the surface of the sample.

3. Results and discussion

The structural properties of the superconducting compound were studied under pressure (8 ton/cm2) and temperature (800 °C) when substituting with (Y_2O_3) nanoparticles of barium element with ratios (y=0,0.1,0.2, 0.3), X-ray diffraction study of these samples showed that all samples possess a polycrystalline crystal structure and contain a mixture of two phases, the first phase is the high main phase (High-Tc-Phase) and the second phase is the low phase (Low-Tc-Phase). In addition to the presence of impurity phases in addition to other phases, it is indicated by the symbol (L, H). In addition to the regularity of the positive ions, which work to compact the atoms along the (c) axis and eventually result in a change in the crystalline structure, the researchers believe that the appearance of different phases in the sample is caused by atomic structure displacement or a change in the oxygen ratio. [14-15].

Miller coefficients (hkl) were found using the (X'Pert High Score Plus) program, and the best match was found between the models for the $Bi_2Ba_{2-y}\,Y_y\,Ca_2Cu_3O_{10}$ compound, The findings demonstrated that all the samples are of the orthorhombic type, and then the phase ratios were determined following the determination of the peaks, their types, and intensities from the (XRD) charts, calculating the compaction factor (c / a) and the theoretical density of. These results are attributable to the sintering time and temperature, which demonstrate that increasing both the sintering time and temperature results in a longer time and more energy. Mass-Transport To get a particle overlap that minimizes the particle's large distance while increasing their size, To create thermodynamically balanced phases, a lengthy sintering process is necessary since the different phases' compositions require layers of (CuO) and (CaO), and thus produces favorable outcomes for samples with higher phase configuration [15,16]. Figure 1 shows X-ray diffraction patterns for samples synthesized using the solid-state reaction technique of the compound (Bi2Ba2-yYyCa2Cu3O10+) by partial substitution of nanoscale yttrium oxide (Y2O3) in barium (Ba) with ratios (y = 0.0.1, 0.2, 0.3). Table (1) shows that all of the samples in the experiment have a rhomboid polycrystalline structure. Furthermore, when the compensation ratio is changed, the partial replacement of yttrium nanoparticles causes the diffraction values to shift and the intensity of the other values to change. Where the results showed that the best increase in the percentage of the high phase at the ratio y = 0.1, which indicates the crystal regularity when compensation and the compound takes a better role in the crystal structure as in Table (1).



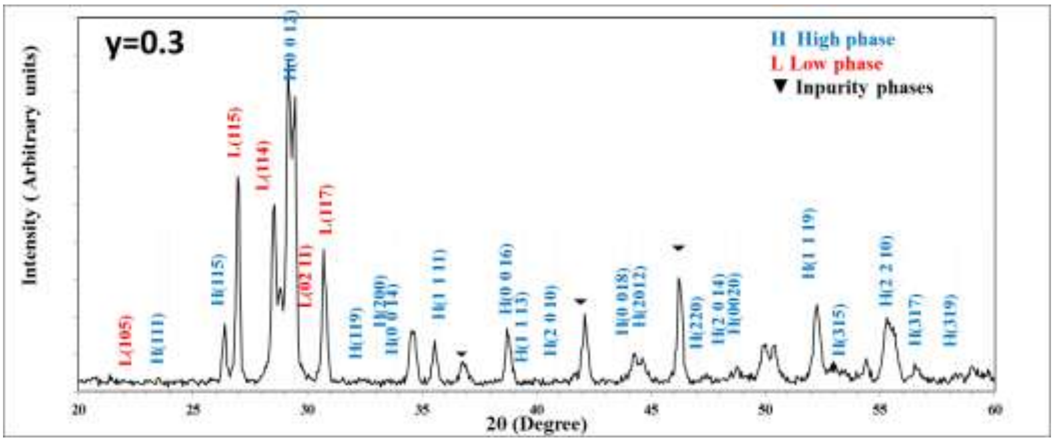


Figure 1: X-ray diffraction pattern of the compound ($Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+\delta}$) with y = 0, 0.1, 0.2 and 0.3

Table (1) represents the values of X-ray constants, high phase ratio, stacking intensity, and c/a for Sb compensation with ratios (y=0,0.1,0.2,0.3) for the compound ($Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+\delta}$)

y	a (Å)	b (Å)	c (Å)	V (Å3)	c/a	w (g/mole)	ρ_m (g/cm3)	HTP %
0	5.4266	5.5125	36.4047	1089.017	6.709	1123.40	8.564	67.57%
0.1	5.4157	5.4317	36.4969	1073.605	6.739	1118.56	8.649	74.76%
0.2	5.4218	5.4088	36.5598	1072.129	6.743	1113.72	8.624	61.42%
0.3	5.4103	5.6432	36.3609	1110.1	6.721	1108.88	8.292	59.60%

Figure (2) represents the relationship between the high phase ratio of the compound ($Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+\delta}$) with y = 0, 0.1, 0.2, 0.3 where the high phase ratio at concentration X=0 was 67.571% and at concentration X= 0.1 The percentage of the higher phase increased to 74.76% and began to decrease at concentration X = 0.2, where it recorded 61.42% and at concentration X = 0.3 it was 59.60%. This change in the values of the higher phase is due to the change in the volumes of the substituted elements, which allow the entry of oxygen into the compound [17].

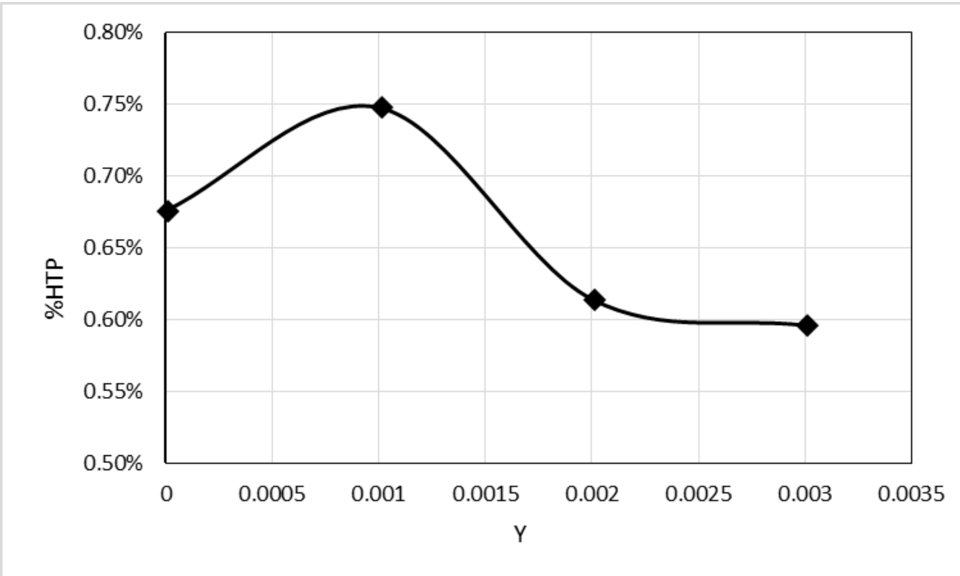


Figure 2: Change of HTP% as a function of the concentration of nanoparticle yttrium oxide for the $Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+\delta}$with y = 0, 0.1, 0.2 and 0.3 compound

From Figure (3), which represents the relationship curve of density (g/cm3) ρm and the concentration of yttrium oxide nanoparticles, we notice that at y=0 the value of (g/cm3) ρm is 8.5636 and at concentration x=0.1 the value of (g/cm3) ρm is equal to 8.649 and we notice The value of (g/cm3) ρm began to decrease at x = 0.2, when it was 8.624, then it became at x = 0.3, equal to 8.292 [18].

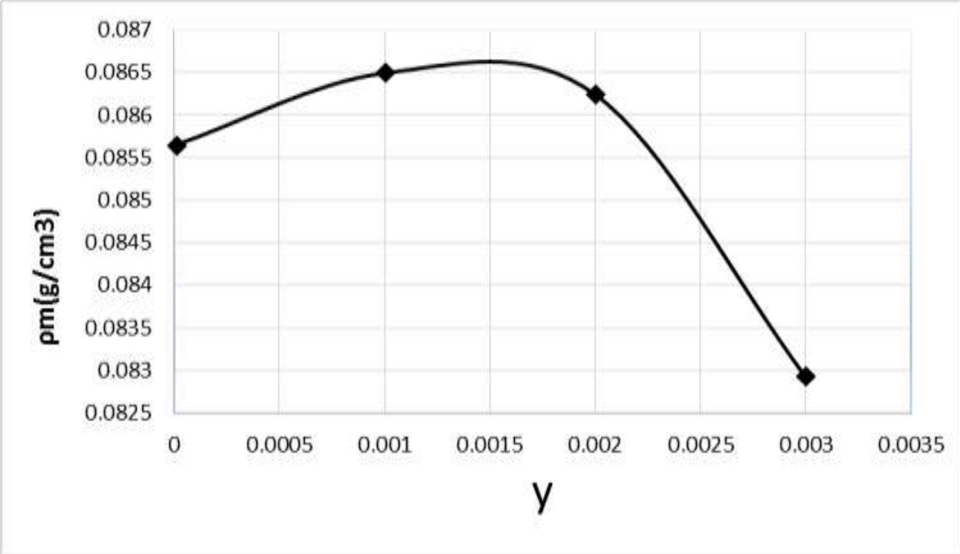


Figure (3) represents the relationship between the density and the concentration of nanoparticles of yttrium

Figure (4) represents the relationship curve between the value of c / a and the concentration of nanoscale yttrium oxide in the compound, where we note that the peak of c / a at y = 0 is 6.709, then it begins to rise until it reaches 6.739 at the value of y = 0.1, and the value of c / a continues to rise Until the value of 6.743 is recorded at the value of y = 0.2, and by increasing the concentration at y = 0.3, the value of c / a begins to decrease, as its value was 6.721.

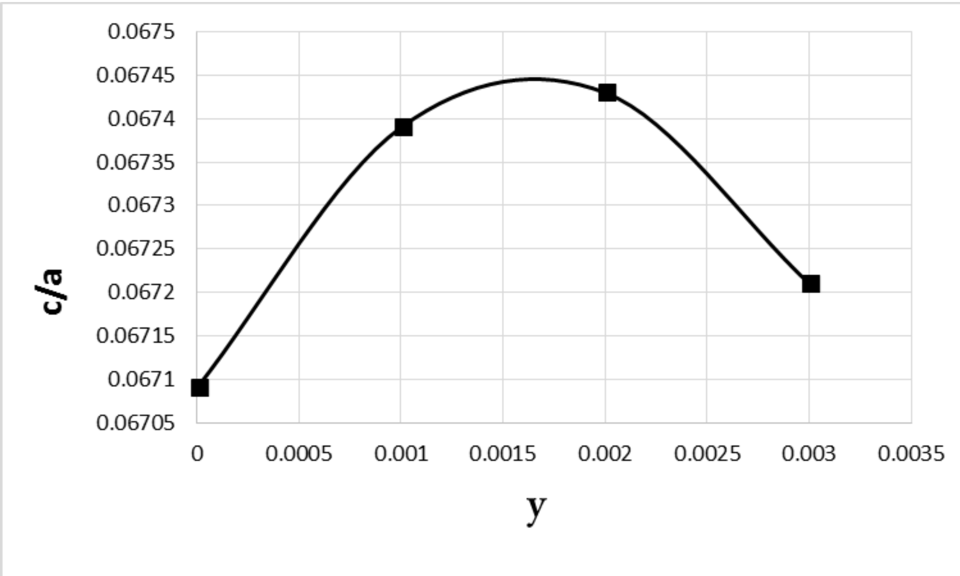


Figure (4) The ratio (c/a) as a function of nanoscale yttrium oxide concentrations

The formation and structure (morphology) of the Bi2Ba2-yYyCa2Cu3O10+ compound with y = 0, 0.1, 0.2, and 0.3 were studied at concentrations and a magnification of 20.0 Kx, where granular formations up to 24 nm in size, as well as the presence of clear homogeneity of the models and the presence of bright areas, were observed. The tests show a change in sizes and the formation of new phases and small granular sizes as shown in Figures (5-8), as a decrease in granular size leads to an increase in the area of the granular boundaries, which in turn helps the movement of current carriers in superconductivity. [19].

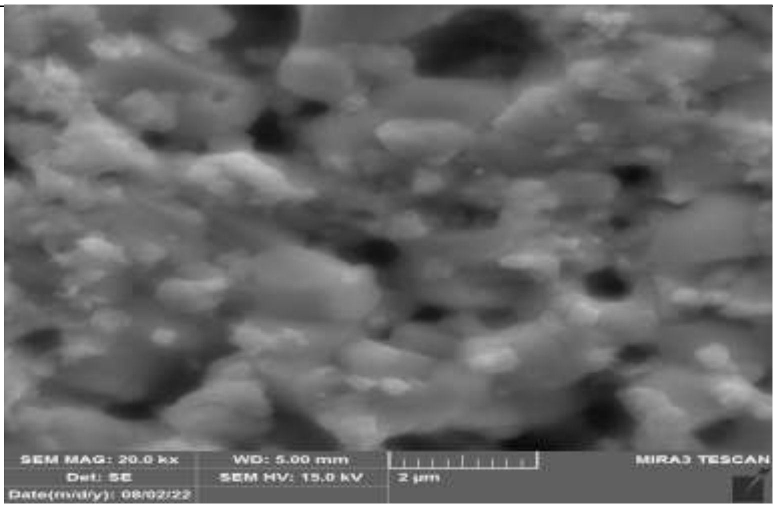


Figure 5. SEM microscopy of the compound ($Bi_2Ba_2Ca_2Cu_3O_{10+\delta}$) when y=0

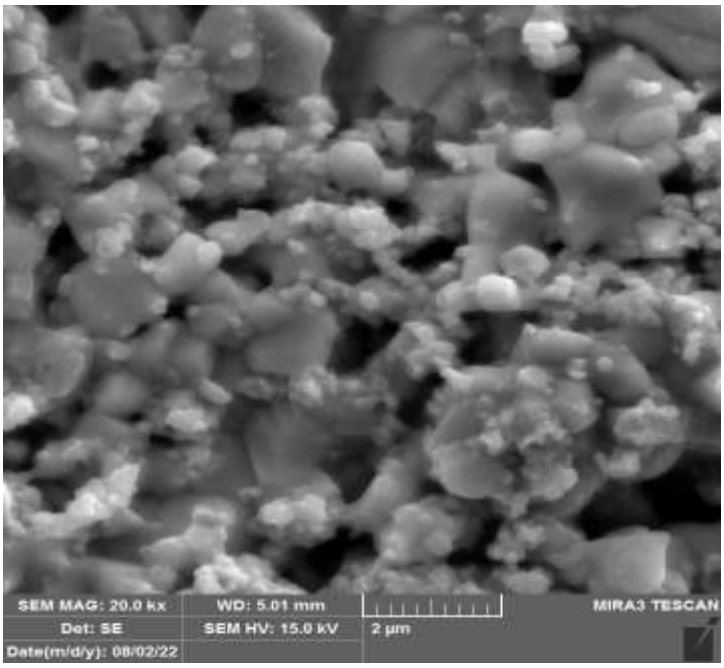


Figure 6. SEM microscopy of the $Bi_2Ba_{1.9}Y_{0.1}Ca_2Cu_3O_{10+\delta}$ compound.

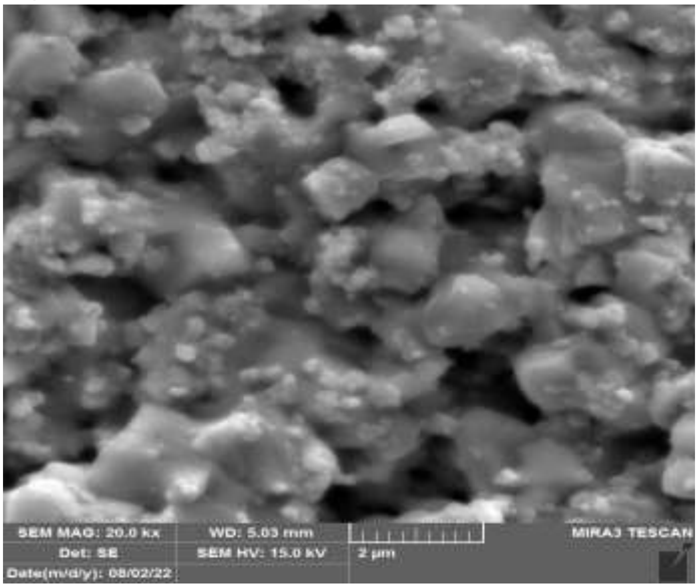


Figure 7. SEM microscopy of the $Bi_2Ba_{1.8}Y_{0.2}Ca_2Cu_3O_{10+\delta}$ compound.

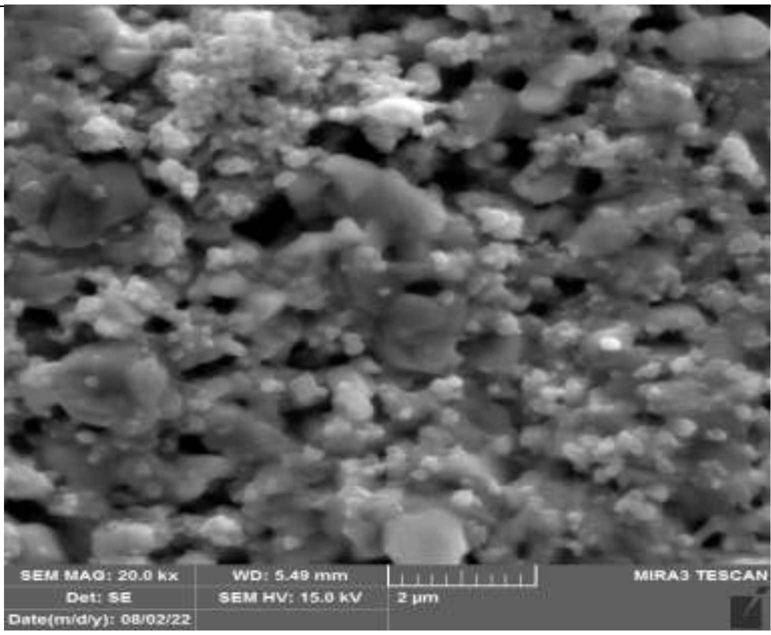


Figure 8. SEM microscopy of the $Bi_2Ba_{1.7}Y_{0.3}Ca_2Cu_3O_{10+\delta}$ compound.

The analysis of the models showed a perfect match between the structural structure of the models and the energy-dissipating X-ray spectroscopy of the models, where the percentage of barium was 15.9 % when y = 0 and became 16% at y = 0.1 and the percentage of yttrium was equal to 1.4% and when the concentration of yttrium oxide increased [20-22], the percentage of barium decreased Where it was 14.8 % when y = 0.2 also, in contrast, the percentage of yttrium increased to 2.9 %, but when the percentage of yttrium concentration increased to y = 0.3, it became 3.9 %, and the percentage of barium decreased to 13.7 %, because the replacement of the yttrium element is in the element bismuth as shown in Figures 9-12.

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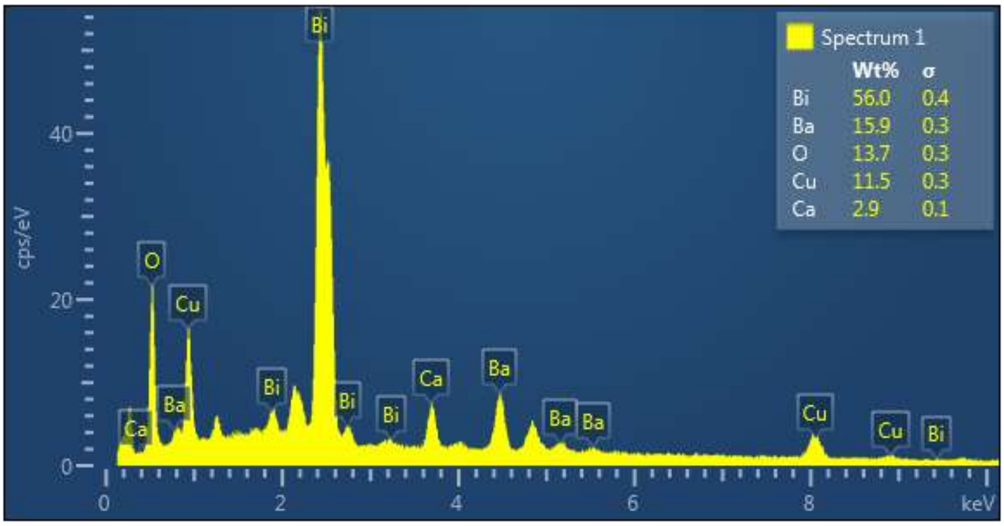

Figure 9. EDX for the ($Bi_2Ba_2Ca_2Cu_3O_{10+\delta}$) compound when X=0

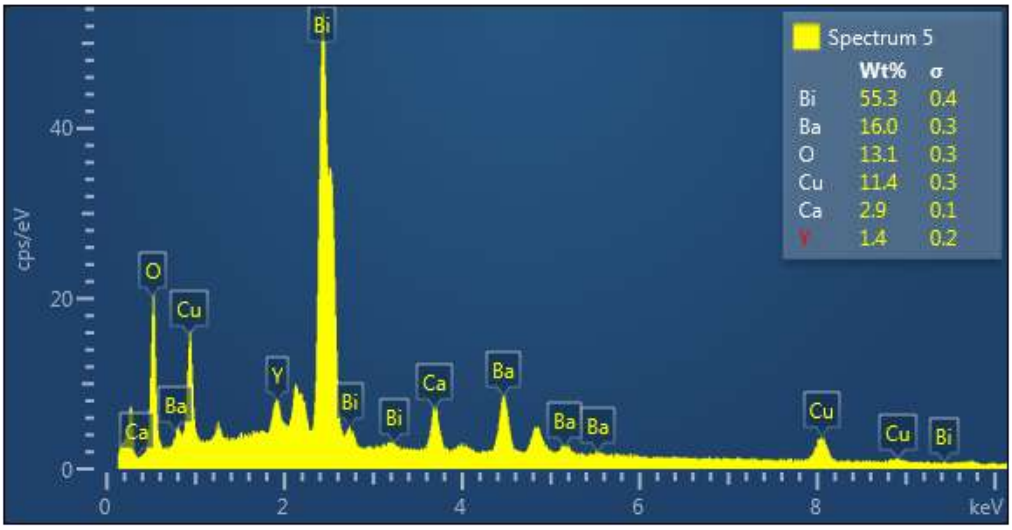

Figure 10. EDX of the $Bi_2Ba_{1.9}Y_{0.1}Ca_2Cu_3O_{10+\delta}$ compound.

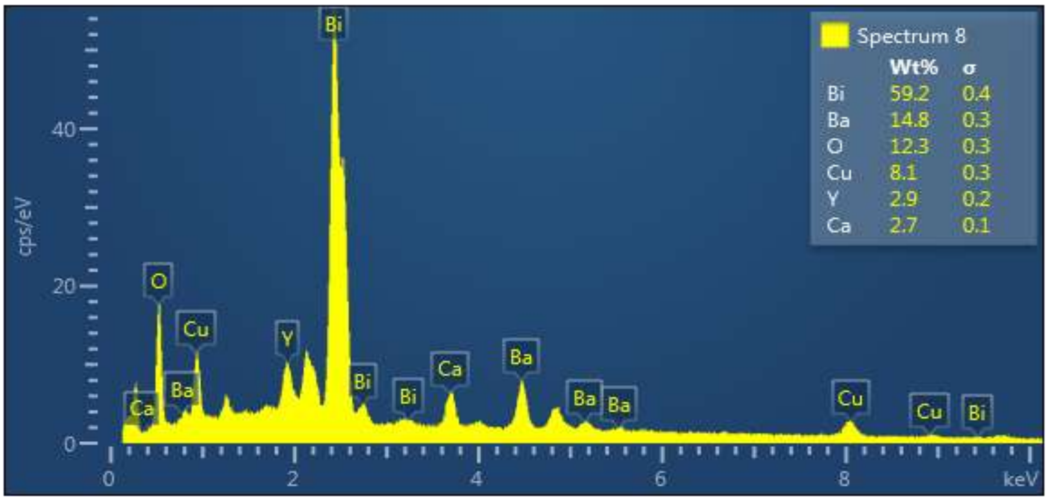

Figure 11. EDX of the $Bi_2Ba_{1.8}Y_{0.2}Ca_2Cu_3O_{10+\delta}$ compound.

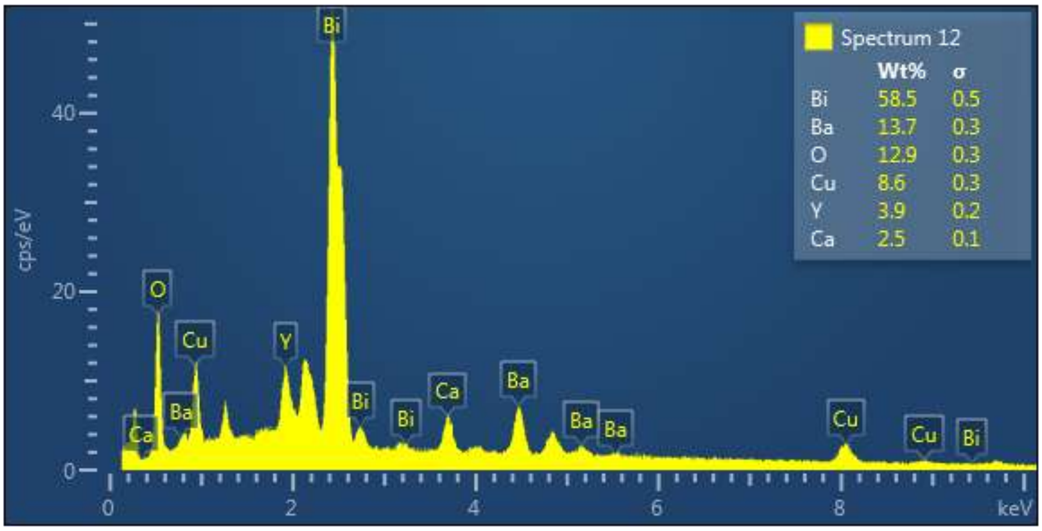

Figure 12. EDX of the $Bi_2Ba_{1.7}Y_{0.3}Ca_2Cu_3O_{10+\delta}$ compound.

Figure (13) represents the relationship curve between the value of ρ (Ω.cm) and the critical temperature. It appears in the figure that the critical temperature when y = 0 is 128 k, but it starts to rise until it reaches 138 k when y =0.1 and returns to decrease when y =0.2 where it recorded 134 K and continues to descend when y=0.3

where the critical temperature was 132 K

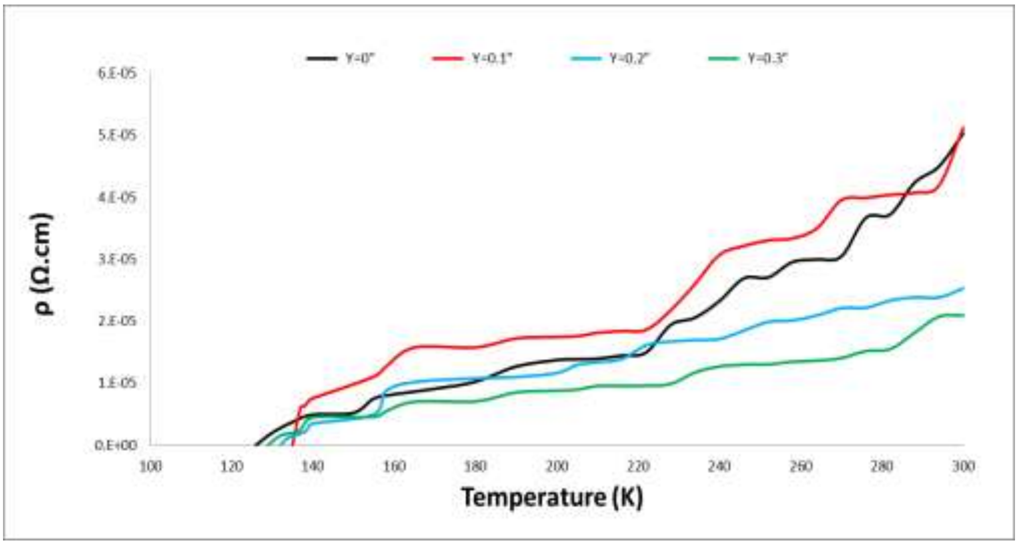

Figure (13) represents the relationship curve between the value of ρ (Ω.cm) and the critical temperature.

4. Conclusions

In this study, we successfully synthesized $Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+\delta}$ with y = 0, 0.1, 0.2 and 0.3 compound. The samples were prepared by the solid state reaction process. We investigated the effect of simultaneous doping of yttrium at the barium site of the Bi-O_2 layer in $Bi_2Ba_{2-y}Y_yCa_2Cu_3O_{10+\delta}$ with a particular focus on the correlation between the observed microstructural properties. XRD data collected from different samples show that all samples are polycrystalline and correspond to the Bi(Sb)-1222 phase. The SCM tests at EDX showed that the surface shapes of the samples were greatly affected with the increase in the concentration of the yttrium element, due to the presence of a difference in the sizes of the substituted elements. The results also showed a clear increase in the critical temperature when replacing the yttrium oxide nanoparticles, which reached 138 K, which led to the improvement of the superconducting property in this compound.

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