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| Research Article

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The Effect of Relative ni Substitution on the Structural Characteristics of the Superconductor Compound Bi2Ba2Ca2Cu3O10-Δ

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Annotation

In this research, two samples were manufactured by the solid-state reaction method and using two methods of sintering and annealing, under a pressure of 8 ton/cm² and a temperature of 820 °C. In the first sample, the nickel element Ni was partially replaced by the copper element Cu at a ratio of X=1, and in the second sample the nickel element Ni was partially replaced by the copper element Cu by X=2 to become the compound Bi2Ba2Ca2Cu3-xNixO10+δ. The unit cell dimension values were: a = 5.4179 (Å), b = 5.5786 (Å), C = 36.5693 (Å), c/a ratio = 6.7498, density = ρm (g/cm3) = 6.7210, and HTP% = 70.34%. From observing the values It has an orthorhombic structure, and when = c/a and the density is 6.7388 = ρm (g/cm3) and HTP% = 67.17%. From observing the values, they are of an orthorhombic structure. Examinations of the two models in the SEM device showed the first model When x=1 At 30.00kx magnification, the grain size formation ranging from 191.6nm to 492.3nm was found to be clear and homogeneous. As for the second model, when x=2 With a magnification power of 30.00kx, a formation of grain size ranging from 96.89 nm to 6 343 nm was found, with clear, homogeneous, and compact images.

Keywords: superconducting, Nickelates, structural properties.

1- Introduction:

Superconductivity can be defined as the sudden drop in specific resistance to a certain temperature called the critical temperature. Increasing the temperature above the critical temperature returns the material to its normal state. Also, the magnetic flux can be completely expelled from the body of the material [1]. In 1986, the two scientists Bednorz and Muller discovered the compound Ba-La-Cu-O with Tc = 35 K, and it was the starting point for what is known today as high-temperature electrical superconducting materials [2] At the beginning of the year (1987) there was a leap in superconducting compounds, as the scientist Wu.et al. discovered. The system Y-Ba-Cu-O, known as (YBCO), has a temperature of Tc = (90-100) K [3]. After that, research continued to discover a compound that has a higher Tc than the system YBCO, and the result was positive at the beginning of the year (1988). Research has resulted in the discovery of the system (BSCCO), which has a Tc higher than 105 K, by researcher Maeda et al [4]. Superconductivity is one of the most prominent phenomena and is a clear example of quantum effects that operate on a microscopic scale in electrically superconducting materials. A state of condensation occurs for a certain portion of the electrons, through which a "large cloud" is formed that extends completely over the volume of the system, and is able to move at zero temperature completely. The collection and condensation of electrons is completed, and thus the superfluid is formed.[5] From the study of materials science, knowledge of the elastic behavior of superconducting crystalline solids is essential and the choice depends on the field of appropriate applications for these materials. This is achieved by knowing the elastic constants and their coefficients[6]. True perovskites are composed of calcium, titanium, and oxygen in the form $CaTiO_3$. Meanwhile, the perovskite structure is anything with the general form ABX_3. Depending on the atoms/molecules used in the structure, perovskites can have an impressive array of interesting properties, including superconductivity and Ferroelectric [7]. Ceramic materials with low particle dimensions are characterized by their mechanical properties, increasing the degree of hardness of metal materials and their alloys and their resistance to pressure due to the presence of large numbers on the surfaces, which means the production of new materials. The chemical activity of increasing the number of atoms on the outer surfaces of materials leads to an increase in chemical reactivity [8] The Nickelates are potential isotopes of copper compounds because nickel is located directly next to copper in the periodic table. A research team has verified that the electronic structure of nickel is similar to the structure of copper materials by taking spectroscopic measurements of X-ray absorption using the Advanced Photon Source [9]. A research team studied the effect of the Ca-O layer and Cu-O layer on the properties and crystal structure of the superconducting compound $Bi_2Sr_2Ca_{n-1}Cu_nO_{2n+4+\delta}$, by examining their impact on the lattice parameters a, b, and c. The c/a ratio increased with increasing (Cu-O layer and Ca-O layer)n [10]. The effect of sintering rate and time on the electrical resistivity, phase type, and crystalline morphology of the superconducting compound made by the solid-state reaction method was also demonstrated. Changing the sintering rate significantly changed the lattice parameter, c/a ratio, and density ρ_m [11] The effect of sintering, calcination and annealing processes on the crystalline structure of powders in the solid-state reaction of superconducting compounds, as sintering contributes to the bonding of powder particles to increase their strength and cohesion and leads to a change in the crystalline structure and the growth of grains. Calcination works to get rid of volatile materials and causes reduction and oxidation, which leads to a change in the chemical structure. Annealing leads to improving plasticity and the transfer of atoms to stable sites within the crystal lattice, thus changing the grain size. [12]

This research aims to study the crystalline structure similar to that of copper compounds. Nickel oxides have long been considered potential analogues for copper compounds, and to arrive at the best partial replacement ratio for the Ni element from the copper element Cu for the compound $Bi_2Ba_2Ca_2Cu_3O_{10+\delta}$ Super electrical conductivity.

2- Stages of samples preparation:

2-1 Calculating the weight ratios of the elements:

Improving the design tool for superconducting materials, especially in superconducting ceramic composites, is important because these materials are characterized by brittleness, cracking tendency, and inability to bend. By doping or partially replacing materials or elements with distinctive specifications, we can obtain new materials that have the property of superconducting and a new mechanical design with regard to the properties of ductility, durability, and distinctive bending strength[13].The weight percentages of the materials that participate in the formation of the compound ($Bi_2Ba_2Ca_2Cu_{3-x}Ni_xO_{10+\delta}$) were calculated, with compensation ratios of X=1 and It was prepared using solid state reaction technology and by sintering and annealing methods[14]

The following tables show the weights of the chemicals used in preparing the various compounds

Table (1-1) Powder weights of the compound $Bi_2Ba_2Ca_2Cu_{3-x}Ni_xO_{10+\delta}$ x=1

Weight	gm/1000	Atomic Weight gm	الالpowder
ɯ1	0.465957	2[0.5 (2*208.98)+(3*15.999))]=465.957	Bi_2O_3
ɯ2	0.306652	2 (137.327+15.999)=306.652	BaO
ɯ3	0.112154	2(40.078+ 15.999) =112.154	CaO
ɯ4	0.15909	2(63.546+15.999)=159.09	CuO
ɯ5	0.0746924	1(58.6934+15.999)=74.6924	NiO

Table (1-2) Powder weights of the compound $Bi_2Ba_2Ca_2Cu_{3-x}Ni_xO_{10+\delta}$ x=2

Weight	gm/1000	Atomic Weight gm	الالpowder
ɯ1	0.465957	2[(2*208.98)+(3*15.999))]=465.957	Bi_2O_3
ɯ2	0.306652	2 (137.327+15.999)=306.652	BaO
ɯ3	0.112154	2(40.078+ 15.999) =112.154	CaO
ɯ4	0.079545	1(63.546+15.999)=79.545	CuO
ɯ5	0.1493848	2(58.6934+15.999)=149.3848	NiO

2-2 Composition of samples:

1-The weights of the powders (ɯ1, ɯ2, ɯ3, ɯ4, ɯ5) are mixed according to Table (1-1) and (1-2), which include, NiO, CuO CaO, BaO, Bi2 O3 to obtain the compound Bi2Ba2Ca2Cu3-xNixO10+δ With the substitution ratios X=2, Isopropanol during the grinding process in order to avoid falling or losing parts of the powder during the grinding process. The second stage was carried out using a vortex electric mixer, which uses a mechanism of stainless steel balls, with a period of 3 hours. The goal of this process is to obtain homogeneous and fine powders that are then placed in an oven. Electrically, at a temperature ranging between (120˚C - 100˚C) in order to get rid of isopropanol alcohol.

2- These powders are pressed into tablets under pressure (8 tons/cm^2). The diameter of these tablets is (15mm) and their thickness ranges from (0.8mm) to (1.2mm).

3-The two prepared samples were shaped into cylindrical discs using a 15 mm diameter mold, and the samples were compressed through a hydraulic press under a pressing pressure of 8 ton/cm2 for three minutes.

2-3 Sintering the samples:

These two models are assembled inside the convection oven in an air-saturated atmosphere and the temperature is raised at a rate of 120˚C/hr until it reaches 800˚C. These models remain for 12 hours at a temperature of 800˚C, then the models are cooled until they reach the temperature The room has a cooling level of 30°C/hr , as shown in Figure (1-1).

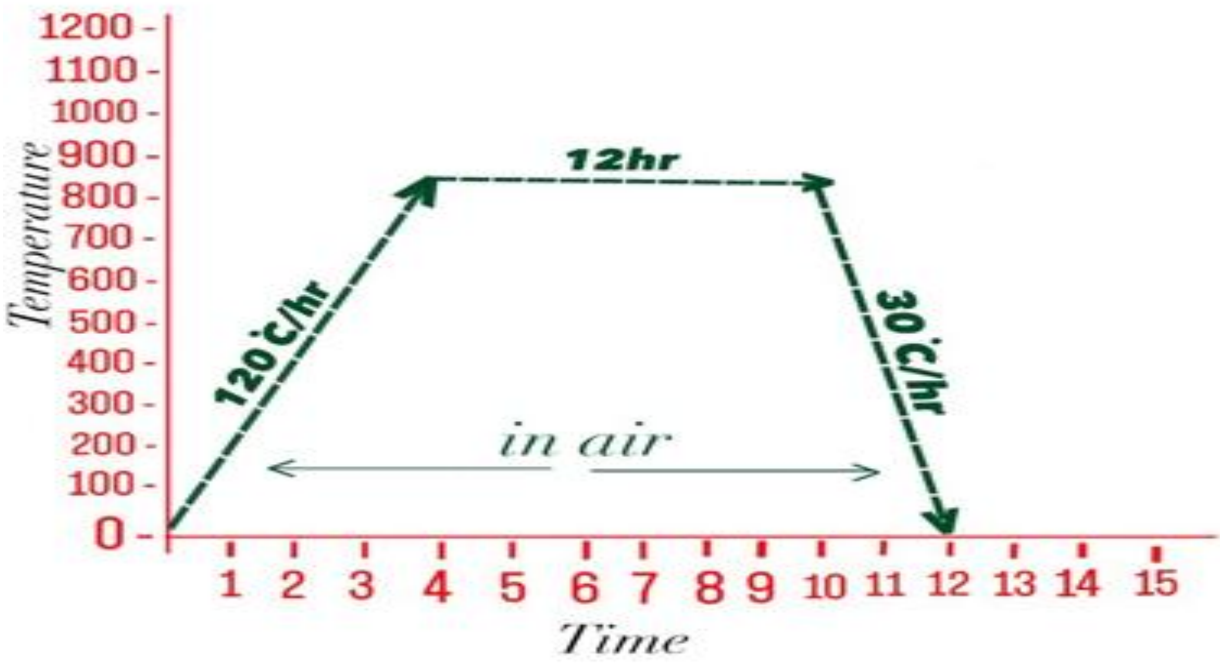

Figure (1-1) A diagram of the heating and cooling processes in an air atmosphere

2-4 Annealing the samples:

The two sample preparations obtained in tablet form from the previous paragraph are combined. It is placed in an electric oven and its temperature is raised from room temperature to 600˚C at a rate of 120˚C/hr. The sample remains at this temperature for 12 hours, after which the oven temperature is raised from 600˚C to 800˚C and at a level of 120˚C/hr and remains at This temperature is maintained for 24 hours in an atmosphere saturated with oxygen, then the temperature of the model is reduced from 800˚C to 600˚C at a rate of 30˚C/hr. It also remains at this temperature for 12 hours, after which the temperature is reduced from 600˚C to Room temperature at a rate of 30˚C/hr. Figure (1-2) shows the annealing process of the compound [15].

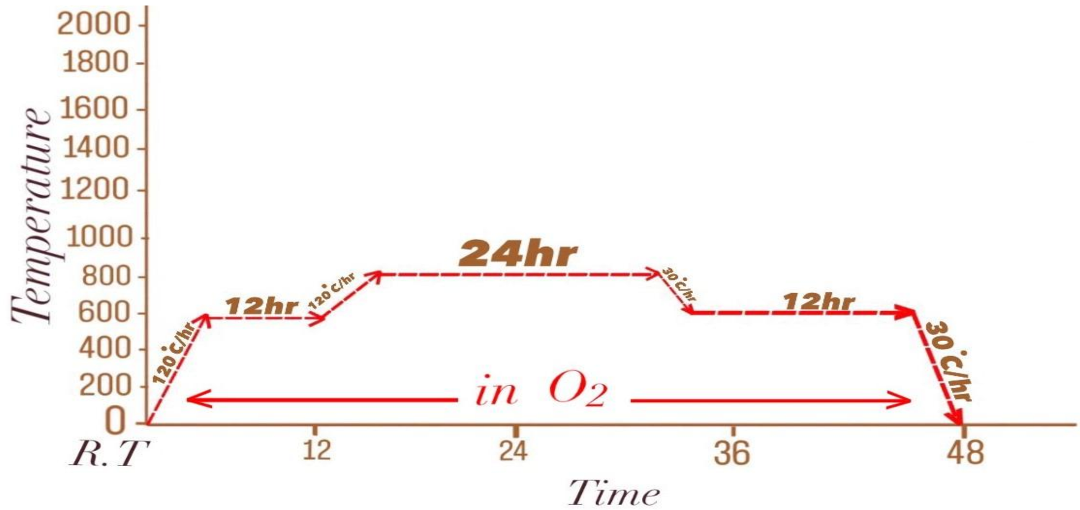

Figure (1-2) Schematic of the annealing method for a superconducting compound in an oxygen-saturated atmosphere.

3- Results and discussion:

An X-ray diffraction study of the Bi2Ba2Ca2Cu3-xNixO10+δ compound when X = 1 and X = 2 Figure (1-3) showed a clear comparison that the difference between the two models through the peaks we notice that the addition of particles has very clearly affected the crystal structure of the samples. The appearance of very sharp peaks is evident in the first sample when X = 1, a clear improvement and regularity in the crystal structure, which was better and showed perfection. In the second sample when X = 2, we notice a limited decrease in the intensity of the peaks, meaning that the process of increasing the concentration of particles has led to changes in the structural composition of the samples. Using the X'Pert HighScore Plus program and Braak's law in diffraction, Table (1-3) and Table (1-4) were obtained, and through these tables the values of Miller's coefficients (hkl) were calculated, then the values of the unit cell dimensions were calculated when replacing nickel Ni with a ratio of X = 1 of the value of the copper element Cu, and the values of the unit cell dimensions were calculated, where a = 5.4179 (Å), b = 5.5786 (Å), C = 36.5693 (Å), and the ratio c/a = 6.7498. The density is ρm = 6.7210 (g/cm3) and HTP% = 70.34%. By observing the values, it is clear that its structure is orthorhombic. When nickel (Ni) is replaced by X = 2 where a = 5.4311 (Å), b = 5.5531 (Å), C = 36.3926 (Å), the ratio = 6.7008 c/a, the density is ρm = 6.7388 (g/cm3), and HTP% = 67.17%. By observing the values, it is clear that its structure is also orthorhombic.

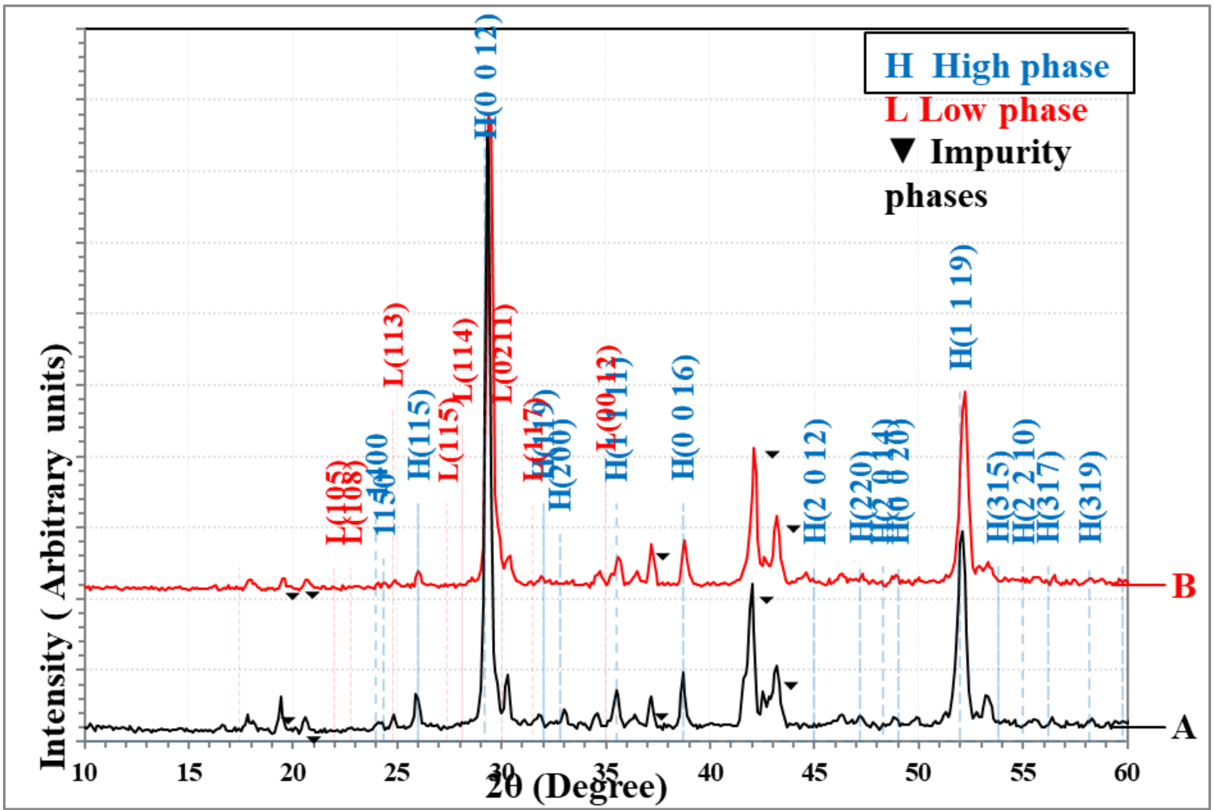

Figure (1-3) X-ray diffraction pattern of the compound $Bi_2Ba_2Ca_2Cu_{3-x}Ni_xO_{10+\delta}$ When x=1 and the compound Bi2Ba2Ca2Cu3-xNixO10+δ when x=2

Table (1-3) mesh parameters a, b, c, ratio (c/a), size and density of group A

x	a (Å)	b (Å)	c (Å)	V ($Å^3$)	c/a	w (g/mole)	ρ_m (g/cm^3)	HTP %
1	5.4179	5.5786	36.5693	1105.276	6.7498	1118.549	6.7210	70.34%
2	5.4311	5.5531	36.3926	1097.576	6.7008	1113.697	6.7388	67.17%

				2	2	2	3-x	x	10	
X	a	b	c	Bi	Ba	Ca	Cu	Ni	O	w
1	5.4179	5.5786	36.5693	208.98	137.327	40.078	63.546	58.6934	15.9994	1118.549
2	5.4311	5.5531	36.3926	208.98	137.327	40.078	63.546	58.6934	15.9994	1113.697

Table No. (1-4) Miller coefficients in addition to the type of structure, which is orthorhombic for the compound Bi2Ba2Ca2Cu3-xNixO10+δ when x=1 and x=2

	Orth.						المحدد	
	2θ	(sinθ)^2		h^2	k^2	l^2		
1	25.94	0.05037		1	1	25	1152	
	29.28	0.06389		0	0	144		
	58.26	0.23694		9	1	81		
	h	k	l	0.05037	1	25	23.287067	A=
	1	1	5	0.06389	0	144		0.02021
	0	0	12	0.23694	1	81		
	3	1	9	1	0.05037	25	21.964516	B=
	a	b	c	0	0.06389	144		0.01907
	5.41787	5.5786	36.5693	9	0.23694	81		
				1	1	0.05037	0.5111388	C=
				0	0	0.06389		0.00044
				9	1	0.23694		
	Orth.						المحدد	
	2θ	(sinθ)^2		h^2	k^2	l^2		
2	25.99	0.05056		1	1	25	1152	
	29.43	0.06451		0	0	144		
	58.21	0.23658		9	1	81		
	h	k	l	0.05056	1	25	23.173841	A=
	1	1	5	0.06451	0	144		0.02012
	0	0	12	0.23658	1	81		
	3	1	9	1	0.05056	25	22.166801	B=
	a	b	c	0	0.06451	144		0.01924
	5.43109	5.55309	36.3926	9	0.23658	81		
				1	1	0.05056	0.5161151	C=
				0	0	0.06451		0.00045
				9	1	0.23658		

Figure (1-4) and Figure (1-5) shows a clear homogeneity of the sample. The image is of geometric shapes, homogeneous, The microscopic images show a change in the grain sizes and the formation of new phases. The grain sizes are small. The decrease in the grain size means an increase in the area of the grain boundaries, which in turn helps the movement of current carriers in superconductivity.

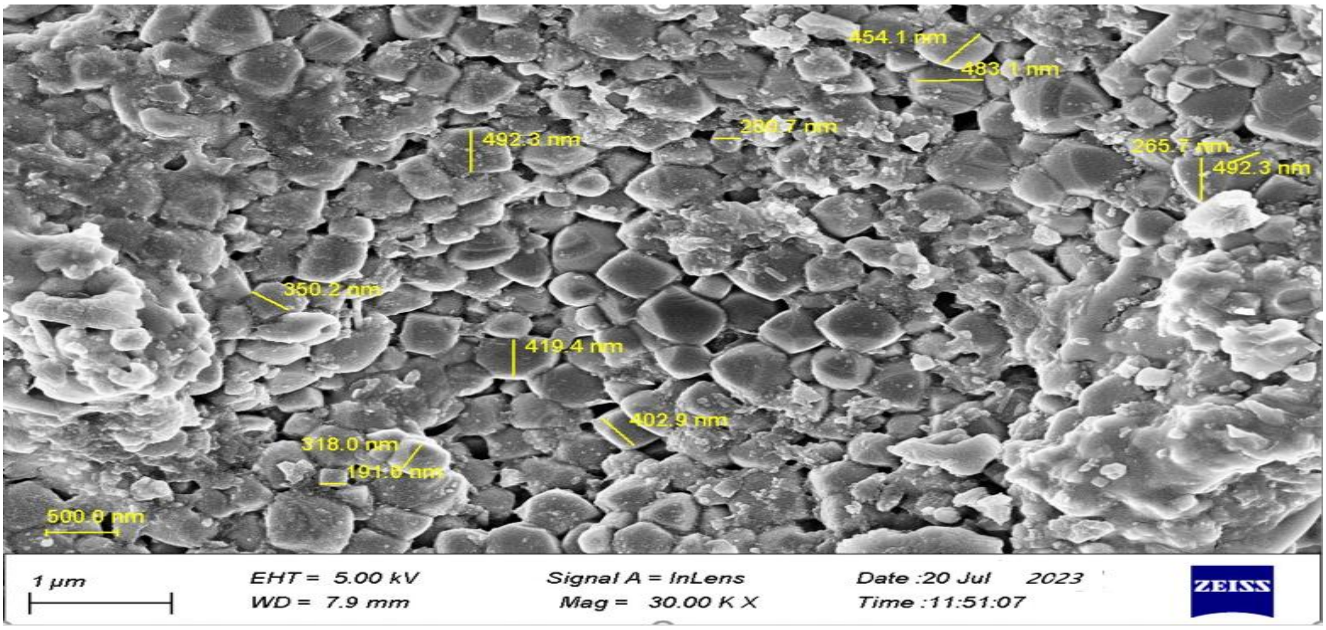

Figure (1-4). Photographs of the compound Bi2Ba2Ca2Cu3-xNixO10+δ for x=1 values with a magnification of 30.00kx

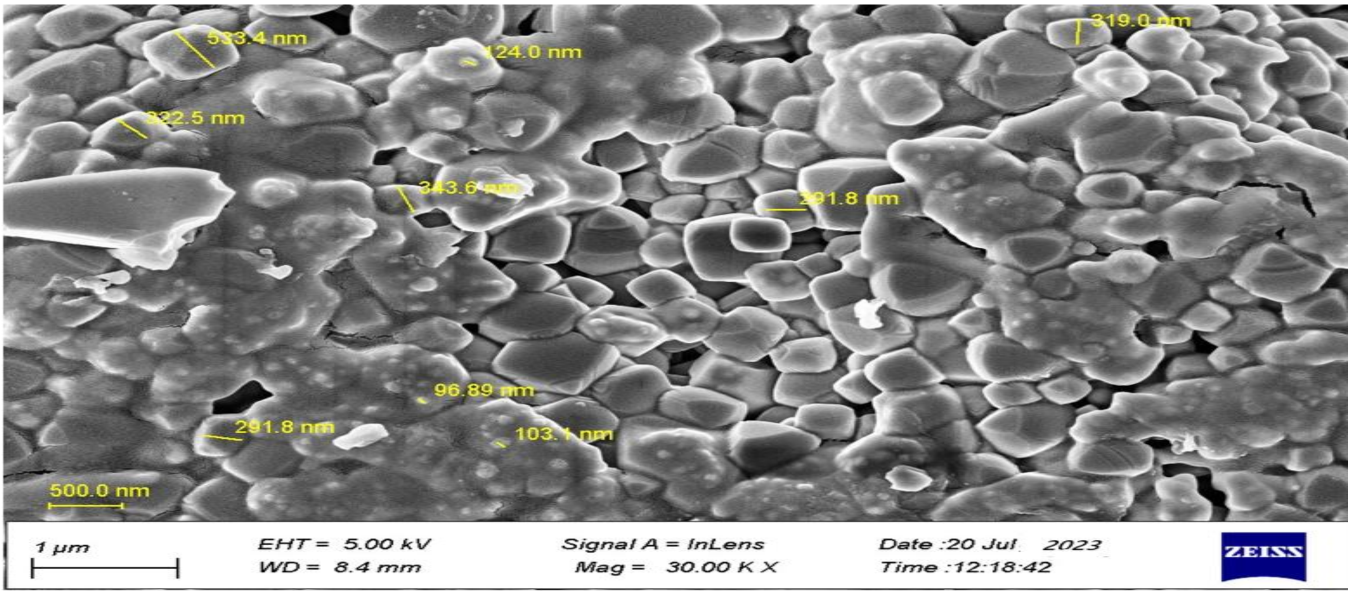

Figure (1-5). Photographs of the compound Bi2Ba2Ca2Cu3-xNixO10+δ for x=2 values with a magnification of 30.00kx

4- Conclusions:

That the increase in the intensity of the peaks of the high phase with a decrease in the intensity of the peaks of the remaining phases, which represent a small percentage. The appearance of different phases in the sample is attributed to a shift in the atomic structure or the regularity of positive ions, which affects the stacking of atoms along the (C) axis, which ultimately leads to a change in the crystal structure and the formation of new phases. The grain sizes are small, as the decrease in the grain size means an increase in the area of grain boundaries, which in turn helps the movement of current carriers in superconductivity. By studying the structural properties, the partial replacement of the nickel element in the superconducting compound Bi2Ba2Ca2Cu3O10-δ will affect the dimensions of the unit cell a, b, and c of the samples in the two models very clearly, while maintaining the rhombic pattern

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