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Effect of the laser CO_2 properties on the superconducting nanocomposite $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ at high temperatures

N. A. Ahmad[a,*], A. K. D. Ali[a], S. H. Mahdi[b]
[a]*Physics Department, College of Sciences, Tikrit University, Tikrit, Iraq*
[b]*Physics Department, Ibn-AL-Haitham Faculty of Education for Pure Science, University of Baghdad, Iraq*

Researchers have been looking into ways to cut down on energy waste in transportation and manufacturing in response to the poor value of energy production as a basic tenet of renewable energy producing facilities. Heat loss due to the electrical resistance of materials is the primary source of energy waste in electrical systems. There are a plethora of studies aimed at lowering material resistance, and the best approach involves the use of superconductor's materials. The number of possible strategies for improving the superconductor's electrical and structural characteristics is overwhelming. Using XRD analysis, a scanning electron microscope, electron dispersive spectroscopy, and the four-probe technique, the authors of this paper report on their findings regarding the effect electrical and structural characteristics for laser-irradiated materials of the $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ compound over a period of 60 seconds. X-ray diffraction studies demonstrated that the crystal structure of the material did not change before and after laser irradiation; both the unirradiated and laser-irradiated samples were found to have an orthorhombic crystal structure. Using the four-probe approach, we looked at how irradiation affected the critical temperature of the specimens we produced. According to the findings of the tests, all of the specimens changed after being subjected to the laser light, with the critical temperature rising by 139 K, 147 K, and 145 K, respectively.

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Keywords: Laser irradiation, Superconducting properties and x-ray diffraction

1. Introduction

One of the biggest issues in the generation, transfer, and distribution of energy is the resistance of materials. Energy loss can be minimized by using the right conductors. The present objective is to create superconductors to aid in the creation of alternative energy sources. Researchers are mulling over a number of options to improve the production of superconductors because they do exist, but only in low-temperature situations. As a result of its crucial oxygen concentration effect on transition and its capacity to maintain a steady flow in a strong magnetic field, $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ is an appealing molecule to obtain. The crystal structure, electron/hole transport, and superconducting properties of $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ are all known to be strongly influenced by the oxygen content. In addition, it has been determined that the critical temperature (Tc) of a superconductor depends critically on the whole density in CuO2 sheets and the percentage of oxygen within each sheet. The sensitivity is proportional to the amount of oxygen present inside the CuO2 planes and the number of holes present in the material. [1]. Pressure or partial ion exchange can be used to adjust the concentration by altering the copper-oxide chemical equilibrium [2, 3]. Multiple reports in the literature detail the results of experiments in which cations were substituted for each of the elements in $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$. The nature of the cation and the site of the substitution determine the effects on superconducting and structural characteristics. It is believed that superconductivity exists in the CuO2 layer, making copper sites the most important of all cationic sites. Because their ionic sizes and orbital configurations most closely match copper's [4, 5], 3D transition elements offer certain

* Corresponding author: noor.ab.ahmad@st.tu.edu.iq
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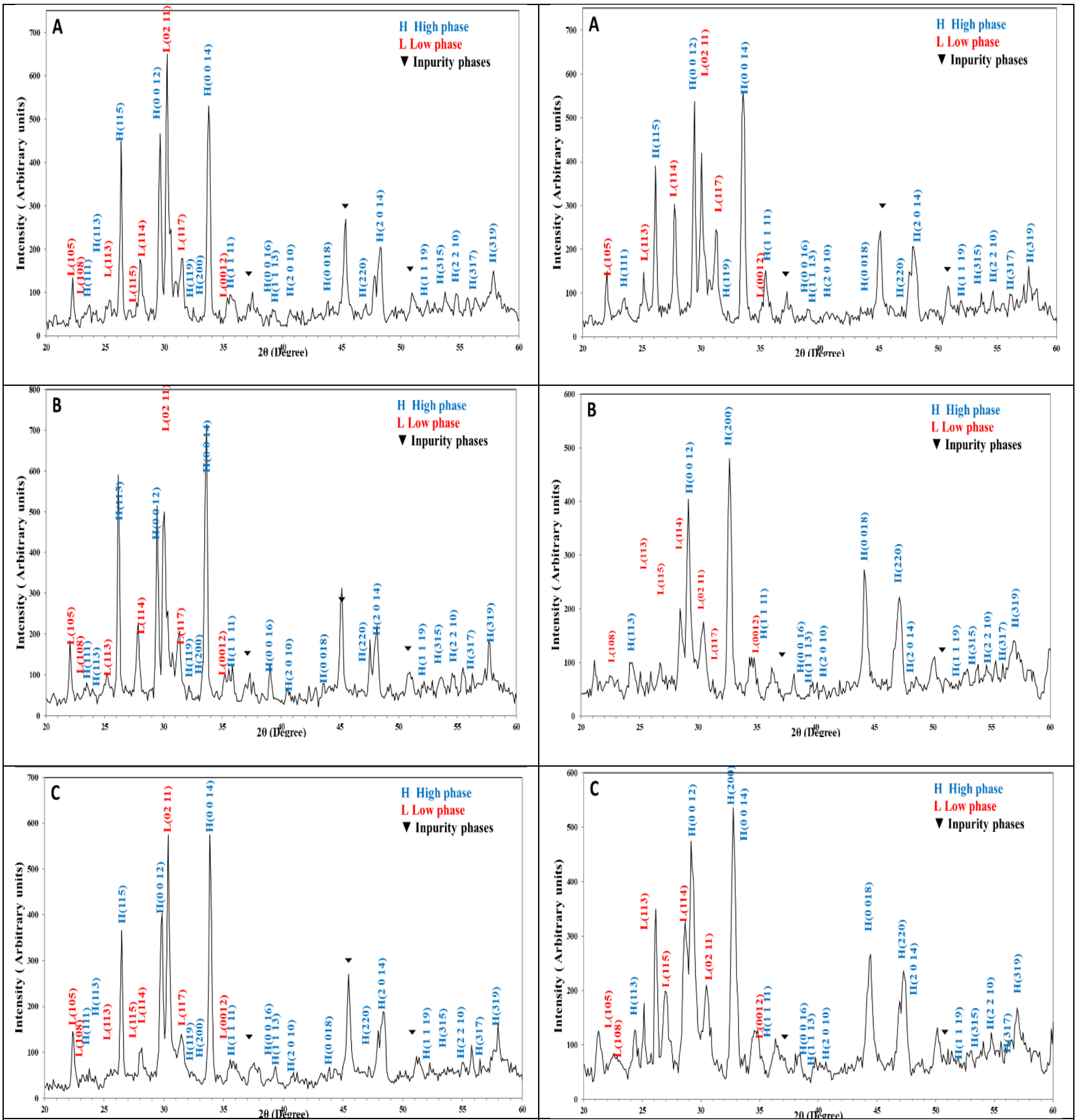
advantageous features for substitutions in the Cu plane. Further, Interchangeable superconductivity in container compounds and the integration of the magnetic transition's 3D components offer promising prospects for the possible interactions of magnetism. Several investigations have shown that the amount of magnetic impurities is more important than that of non-magnetic impurities when it comes to substitute Co, Zn, or Ni ions for Cu ions using high-temperature superconductors [6-8]. Several studies, however, have demonstrated that the mechanical properties and chemical characteristics of $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ can be enhanced through the partial substitution of chemical elements during production. Studies of these flaws are crucial with respect to chemical equilibrium because of their avoidance and their desirability in superconductors. The primary goal of this work is to examine the effects of laser irradiation on the physical properties of the $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ compound, namely the critical temperature Tc, the structural alterations, and the micro-structure.

2. Experimental

Standard solid-state reaction technology was used to generate samples with the nominal composition $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$. Oxides in the right amounts, softened and fully blended over the course of several hours (60-90 minutes). The powder was reassembled and mixed before being placed in an alumina crucible and heated to 800 °C to achieve Centering. In a furnace set to 200 degrees Celsius, the mixture was dried. The powder was divided into three equal containers and labeled. We used a hydraulic pressure machine at 7 tons per square centimeter to compress A, B, and C into pellets with a 0.25-0.30 cm diameter and a 1.5 cm disc shape. After thermally centering the pellets at 800 °C for 120 hours, they were cooled to 27 °C. After that, a diode-laser source (red laser dot module focusable) at 10.6m was used to irradiate the three manufactured specimens (A, Band C). The distance between the laser and the samples was 40 centimeters. After 60 seconds of irradiation, three samples (labeled A, B, and C) were analyzed for their critical temperature of resistance vs temperature using a four-probe approach. References [9-11] were used to derive the formulas and procedures used to determine the density mass and the amount of extra oxygen. Get the structure of your materials with the use of x-ray diffraction (XRD) measurements, a scanning electron microscope, and electron dispersive spectroscopy. Using the Rietveld refinement method [10], one can determine the values of a and c that characterize the crystal structure.

3. Result and discussions

In crystalline materials, the diffraction pattern is unique and determined by crystal composition and structure, also called the final state. The proportional density and location of diffraction peaks can be used to identify distinct crystalline phases from a given set of experimental data. Furthermore, crystal formations can be recognized. Crystalline lattice values were determined using the procedure outlined in Refs. [12-13-14]. Figure 1 shows the X-ray diffraction patterns along the peaks for all three examples (A, B, and C). X-ray diffraction analysis was used to study how laser irradiation affected the structure characteristics of the $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ compound. X-ray diffraction findings showed that there were no phase transformations after laser irradiation, since the irradiated specimens also have an orthorhombic crystal structure. However, there were differences in the peak intensities and estimated lattice parameters. The structural modifications brought on by laser irradiation will be recorded as a series of marks. The preponderance of peaks in each diffraction pattern can be indexed to the $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ phase, suggesting that all samples were prepared using a multi-phase approach. It has been observed that laser illumination causes slight alterations to the locations of diffraction peaks. In Table-1,2 we can see a comparison of the lattice characteristics before and after laser irradiation for three $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ samples.



Before laser irradiation

After laser irradiation

Fig. 1. XRD for the $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ specimens A, B, and C before and after laser irradiation.

Table 1. Lattice parameters of $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ before laser irradiation.

Specimens	x	y	a (Å)	b (Å)	c (Å)	V ($Å^3$)	c/a	w (g/mole)	ρ_m (g/cm^3)	HTP %
A	0.03	0	5.4713	5.5412	36.3931	1103.340	6.652	1024.03	7.705	68.63%
B	0.03	0.03	5.4659	5.5261	36.4912	1102.226	6.676	1023.881	7.711	70.49%
C	0.03	0.12	5.4543	5.5416	36.3642	1099.128	6.667	1023.444	7.730	69.52%

Table 2. Lattice parameters of $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ after laser irradiation.

Specimens	x	y	a (Å)	b (Å)	c (Å)	V ($Å^3$)	c/a	w (g/mole)	ρ_m (g/cm^3)	HTP %
A	0.03	0	5.4899	5.6303	36.3333	1123.059	6.618	1024.03	7.569	67.88%
B	0.03	0.03	5.4868	5.0757	36.8685	1026.757	6.720	1023.881	8.278	71.54%
C	0.03	0.12	5.6598	4.8514	36.6293	1005.767	6.472	1023.444	8.447	70.33%

Figure 2,3 shows the electrical impedance versus temperature for the irradiation condition compared to the pre-irradiation condition a time span of sixty seconds of $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ specimens, from which the critical temperature is calculated. [15-17]. To investigate how irradiation affected the crucial temperature of the samples, the four probes method was used. The results showed that all samples changed after being exposed to laser rays, with some showing a rise in critical temperature of about 139 K, 147 K, and 145 K. Tc=147 K was discovered in Table-3,4 for x=0.03, y=0.03, which is the highest value recorded following laser irradiation

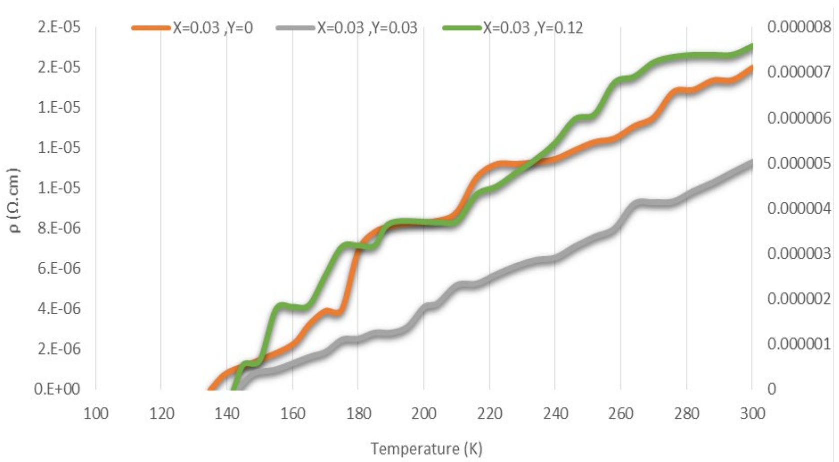


Fig. 2. The relationship between temperature and electrical resistivity for $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$, before laser irradiation.

Table 3. Offset, onset, transition width T(K), and transition time Tc (K), for $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$, before laser irradiation.

Specimens	X	Y	TC onset	TC ofset	TC
A	0.03	0	140	135	138
B	0.03	0.03	148	143	146
C	0.03	0.12	145	142	144

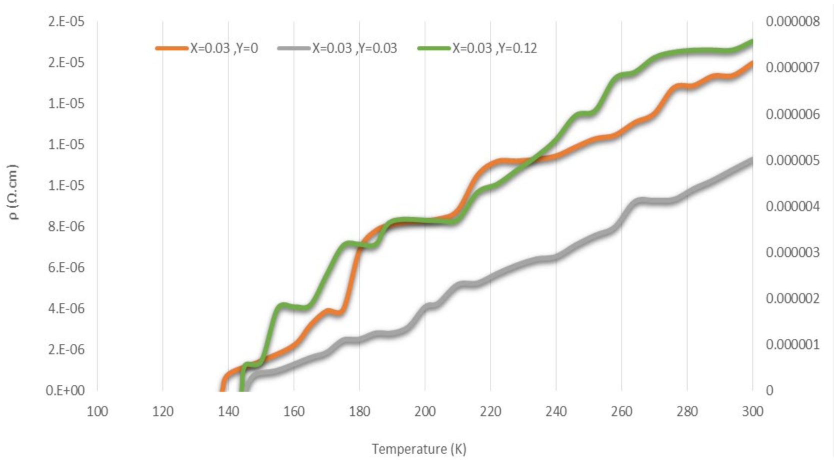


Fig. 3. The relationship between temperature and electrical resistivity for $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$, after laser irradiation.

Table 4. Offset, onset, transition width T(K), and transition time Tc (K), for $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ after laser irradiation.

Specimens	X	Y	TC onset	TC ofset	TC
A	0.03	0	140	138	139
B	0.03	0.03	148	145	147
C	0.03	0.12	145	144	145

3.1. Scanning Electron Microscope (SEM)

The shape of the surface and the typical size of the crystallites can be found using FESEM. FESEM imaging of bulk materials reveals information about grain size, grain development, pore structure, and grain distribution.[18-19] The nanocomposite sample $\mathbf{Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}}$ was scanned by an electron microscope (SEM) before and after being exposed to a laser in Figure 4.

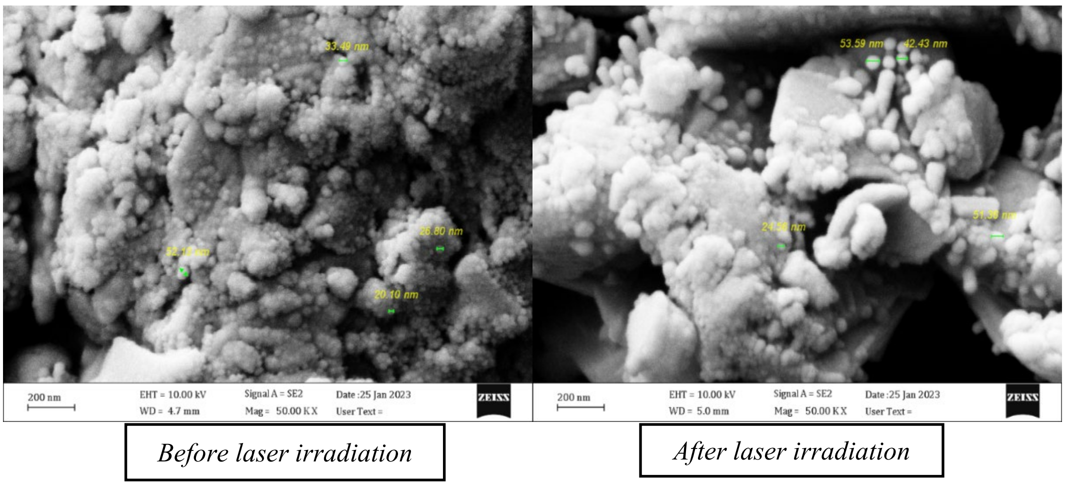


Fig. 4. FESEM for nanocomposite $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ specimen B, before and after laser irradiation where x=0.03, y=0.03.

3.2. Energy Dispersive X-Ray Spectroscopy

EDS is an analytical method used to characterize the chemical or elemental composition of a sample. A type of spectroscopy is spectroscopy. It is based on the examination of a sample while electromagnetic energy interacts with matter. The EDS was connected to the FESEM [20]. We used EDS to confirm the existence of the nano particle composite $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ ingredients, as shown in the figure below. Figure 5 shows the presence of the nanoparticle constituents that make up the composites.

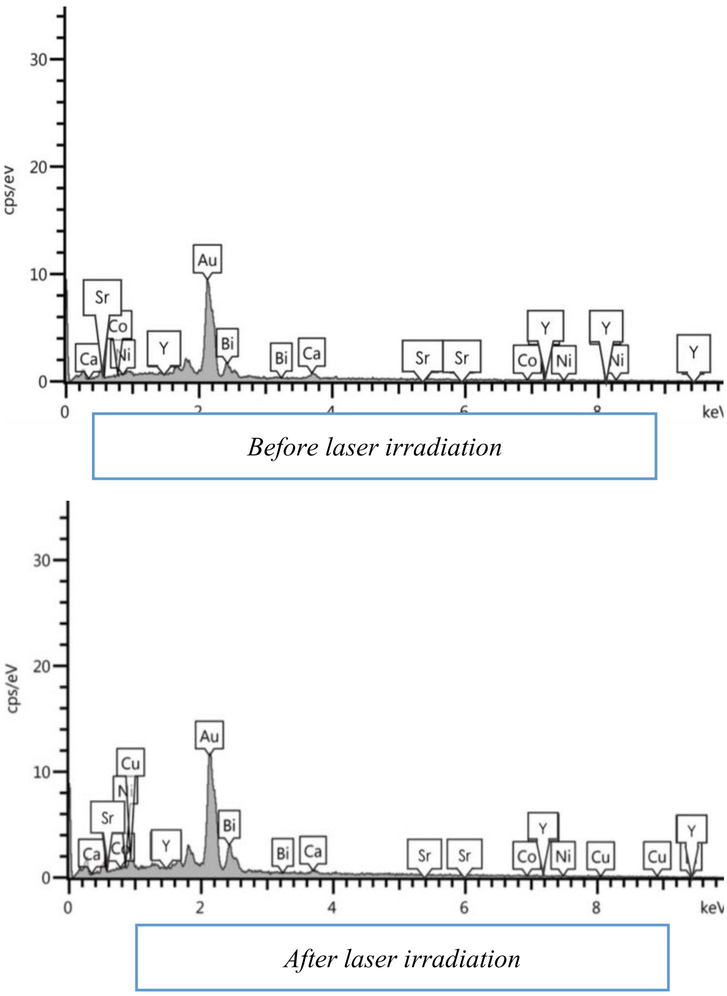


Fig. 5. EDS image of nanocomposite $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ specimen B, before and after laser irradiation where x=0.03, y=0.03.

4. Conclusions

The laser irradiation effects on the $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ system's structural and electrical characteristics have been studied. X-ray diffraction (XRD) studies have been performed to look into the structural changes of the irradiated objects. X-ray diffraction results revealed that the orthorhombic crystal structure of the specimens was maintained both before and after laser irradiation; however, there were differences in the characteristics such as peak intensity, characteristics of the lattice, density of matter, and percentage of volume.

The effect of irradiation on the critical temperature of the prepared specimens was studied using the 4-probe approach.. All irradiated specimens were found to have changed after being exposed to the laser ray, with a rise in critical temperature of 139 K, 147 K, and 145 K respectively. Surface topography and average crystallite size determined by field emission scanning electron microscopy. Using EDS, we were able to verify that the nano particle compound $Bi_2Sr_{2-x}Y_xCa_2Cu_{3-y}Ni_yO_{10+\delta}$ contained all of its expected constituents.

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