Article

Examine the Impact of Partial Replacement of Nickel for Mercury on the Structural Properties

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Abstract:

In this study, the compound $Hg-base$ superconductors $Hg_{x-1}Ni_xBa_2Ca_2Cu_3O_{8+\delta}$ were created by substituting (Ni) with concentrations of $x = (0, 0.1, 0.2, \text{and } 0.3)$ by Hg using the solid state reaction method and sintering it at 820˚ C for 24 hours. Enhancement of Structural characteristics for composition substations was studied. Following the completion of the x-ray scattering tests, By examining the results, the set-up and lattice parameters (a, b, and c) of each cell unit were determined. Each sample has crystals with a tetragonal structure, as demonstrated by x-ray diffraction.

Keywords: X-ray diffraction, AFM , Solid state reaction technology

Introduction

One of the key properties in solid state physics that is examined for many compounds and elements at very low temperatures is the disappearance of resistivity for the material at a particular temperature. This temperature the critical temperature varies based on the type of material due to a phenomena called superconductivity[1].The phenomenon of superconductivity in mercury was originally observed in 1911, when a temperature of about 4K caused pure mercury to lose all of its electrical properties[2]. A general overview of this phenomena was not attained until 1957, when three scientists put out the theory known as the BCS, which governs the beginning of superconductivity [3, 4]. According to the theory of phonon interactions, in certain situations the attraction caused by a sequence of phonon interactions between two conducting electrons may very slightly exceed the repulsion that similar charges instantly experience from one another..[4, 5]. According to quantum theory, some electron pairs will be able to tunnel through this junction and allow electrons to pass past the barrier as waves, as explained by Brian Josephson's

1962 description of the process of creating a superconducting material. Nevertheless, the physical properties of the superconductor can be ascertained because these particles are incapable of doing so and may be studied by the use of the tunneling penetration current [2, 6].

EXPERIMENTAL

The solid-state reaction technique (SSR) was used to create the samples. According to the superconducting system (HBCCO), where high-purity oxide powders are used, the minerals were used in pure oxides. (HgO, NiO, BaO, CaO and CuO) were given the proper weights. Calculating the proper weights from the elemental oxides is the first step in sample preparation. This is followed by grinding the sample using an electric mixer and a manual mortar. Subsequently, the mixture was compressed using a hydraulic piston to create tablet-shaped samples, using pressure of 8 tons per centimeter for minute and a half. The samples were then sintered in an oven specifically designed to achieve an 820 degree Celsius temperature, This degree was specifically chosen based on previous studies that determine the appropriate degree of sintering for this compound between(800-850)degree celsius.The samples were heated (10 °C/min) for 24 hours, and then they were cooled down to room temperature using the same heating rate.

Findings and discussion:

Early in the X-ray diffraction investigation of the superconducting system (HBCCO), the intensity of the high phase ($Hg-1223$) peaks rose, suggesting that a significant portion of the phase is present in the pure sample and that the strength of the peaks for all other phases is diminishing... Apart from the distinct phases that developed in the unadulterated material and the minute quantities of contaminants that were present, the leftover samples additionally comprised trace amounts of contaminants.

Crystallization can occur as a result of defects building up in the stacking along the (c) plane from atom dislocations, oxygen deprivation, or anomalies in positive ions. The sample's lattice constants ($a, b, and\ c$) were then extracted and calculated using X-ray diffraction using Braque's law. by utilizing equation (1), [7].

$$\frac{1}{d^2} = \frac{h+k}{a^2} + \frac{l}{c^2} \text{ .....(1)}$$

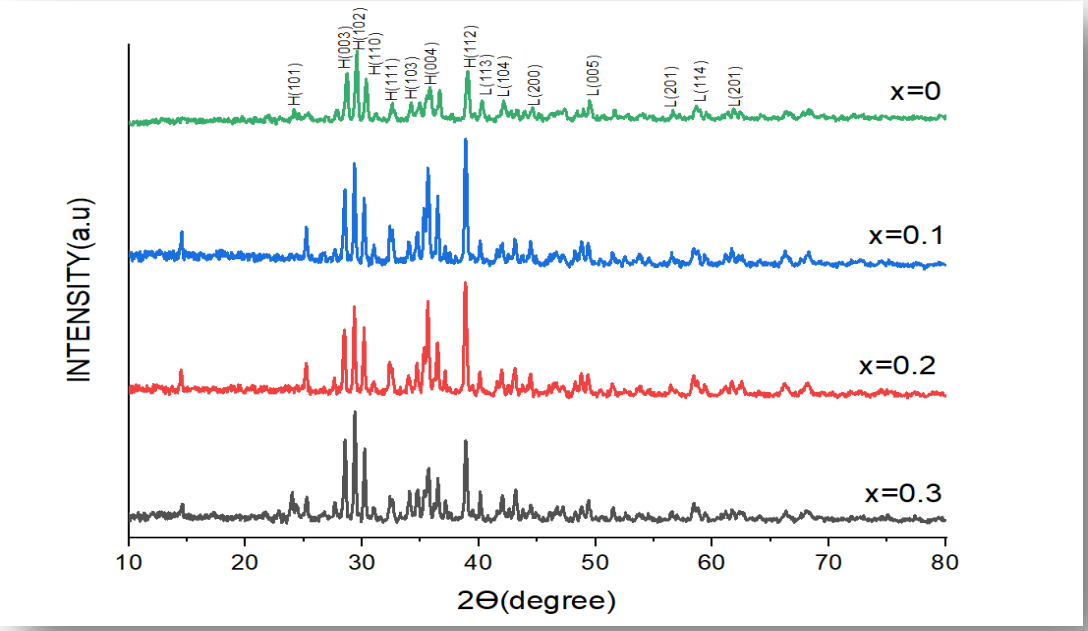


Fig (1) :Intensity as function of 2θ for $Hg_{x-1}Ni_xBa_2Ca_2Cu_3O_{8+\delta}$ compound with x = 0 , 0.1 ,0.2 0.3

After determining the peaks, their strength, and type, the phase ratios were calculated using traditional approaches. The results were remarkably similar to the conventional calculations, indicating that the material possesses a tetragonal crystal structureThe following mathematical process was used to determine each phase's ratio. [8,9].

$$(V_{ph})\% = \frac{\sum I_0}{\sum I_1 + \sum I_2 + \sum I_{other(peaks)}} \times 100\% \dots\dots\dots\dots (2)$$

Where I represent the intensity of the peaks in each phase.

Table (1) shows the phase ratios, lattice coefficients, and (c /a) of the produced samples

X	$V_{ph(H)}\%$	$V_{ph(L)}\%$	$a(A)$	$b(B)$	$c(C)$	a/c
0	53.3%	46.7%	3.8907	3.8907	9.5563	2.4561904
0.1	66.7%	33.3%	3.8731	3.8731	9.4829	2.44840051
0.2	73.3%	26.7%	3.8839	3.8839	9.5380	2.455778985
0.3	66.7%	33.3%	3.8744	3.8744	9.5114	2.4549349577

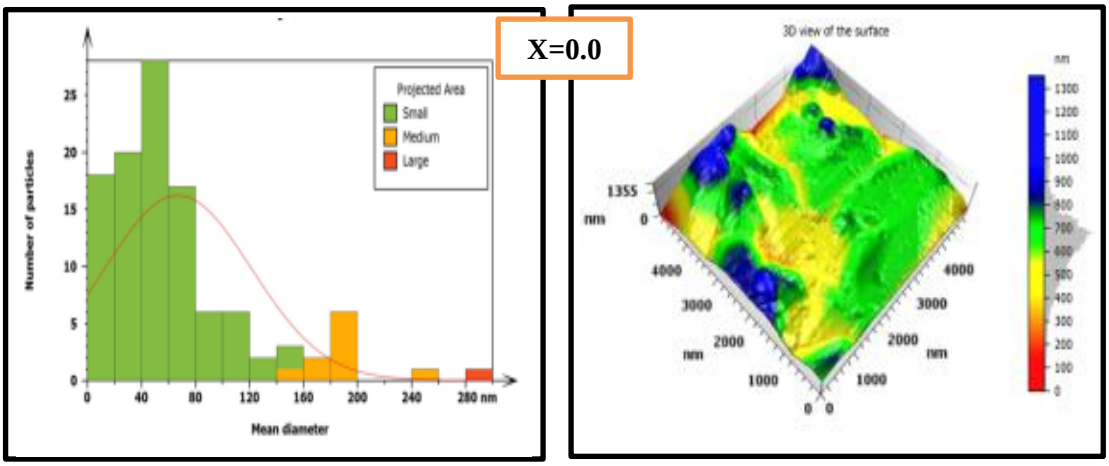
Atomic force microscopy, or AFM, is a great tool for examining the morphology and texture of various surfaces. Research on biological processes in motion, thin film

surfaces, mechanical manufacturing, and tribological properties have all been made possible by the nanometric precision of surface topography knowledge. in contrast to alternative microscopic methods. This method's adaptability enables more thorough analyses and evaluations of the morphological and textural qualities of the films. The roughness parameters (Rq) and (Ra) were used to determine the surface roughness, where the average height over the whole measured length or area is equal to the average roughness (Ra). The square root of the surface height distribution is known as root mean square (RMS) roughness. It is assumed to be more sensitive to considerable departures from the mean line or plane.

$Table(2)$: $average\ roughness\ (Ra), root\ mean\ square\ (RMS)\ Roughness\ (Rq), Mean\ dimeter(nm)\ for\ x = 0, 0.1, 0.2, 0.3$

X	R_a(nm)	R_q(nm)	Mean dimeter(nm)
0	107.1	142	67.01
0.1	184.6	226.3	142.8
0.2	391.3	487	145.8
0.3	185.3	226.6	118.8

According to table (2), changes in the substitution ratio between Mercury (Hg) and Nickel (Ni) have an impact on the values of the mean diameter (nm), average roughness (Ra), and root mean square (Rq). Among other things, the sample with the replacement ratio (Ni=0) had the lowest diameter rate (67.01). Furthermore, a 142 nm Rq value and a 107.1 nm Ra value. Additionally, it was shown that a 0.2 increase in the substitution ratio between the elements Nickel and Mercury causes the mean diameter to rise to 145.8 nm.



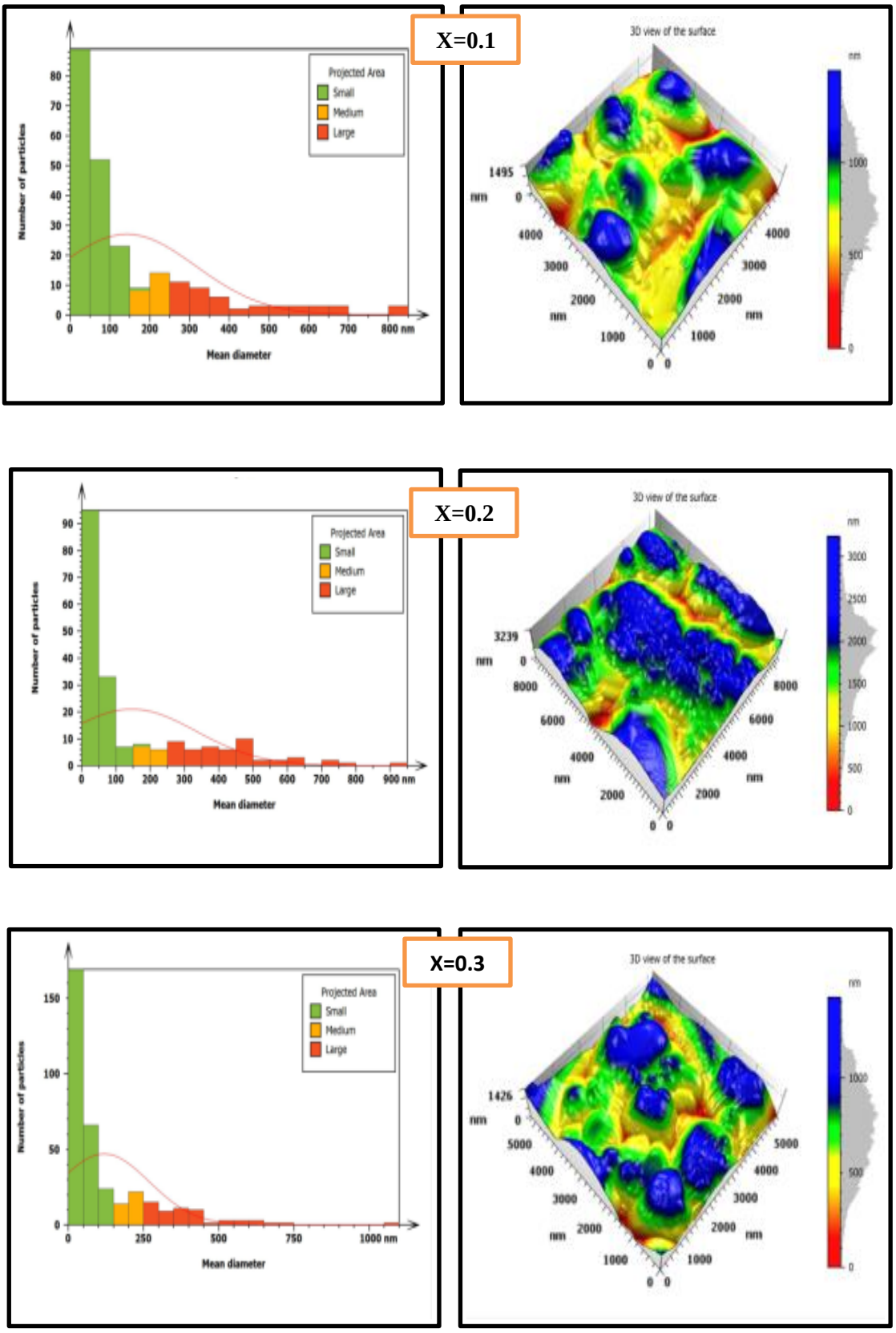


Figure (2) displays the three-dimensional AFM images and the chart distribution of $Hg_{0.8}Ni_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$.

Conclusions

The experimental endeavor investigated the effects of partial substitution of Nickel (Ni) on the compound $Hg_{1-x}Ni_xBa_2Ca_2Cu_3O_{8+\delta}$. We were able to achieve a rise in high phase for the samples under the preparation conditions. The XRD charts and the greatest value of Vph at concentration (x=0.2) indicated that each sample had an Tetragonal structure. AFM techniques were utilized to analyze the image composition of the $Hg_{x-1}Ni_xBa_2Ca_2Cu_3O_{8+\delta}$ system with x = 0, 0.1, 0.2, and 0.3. It demonstrates that at (x=0), there were fewer mean diameters (nm).

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