International Academic Institute for Science and Technology

International Academic Journal of Science and Engineering
Vol. 9, No. 2, 2022, pp. 83-91.

ISSN 2454-3896

International Academic Journal of Science and Engineering

www.iaiest.com

Study of the Synthetic Characteristics of Pure Cobalt - Tinged Nickel Oxide (Nio) Membranes (Co)

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Abstract

The pure nickel oxide ((NiO) doped with cobalt (Co) in different atomic ratios (at.% 3.6.9.12) were prepared by spraying on glass bases at a temperature of (550ºC), where a solution of nickel nitrate ($Ni(NO_3)$ $2.6H_2O$) is a source of nickel (Ni) with a molar concentration (0.2mol/L) and a cobalt chloride solution ($CoCl$ $2.6H_2O$) with the same molar concentration as the previous source of the grafting element (Co), The effect of cobalt grafting on the structural Characteristics has been studied.

The results of the X-ray examinations showed that the prepared Devices were of polycrystalline cubic structure, and the predominant orientation (111) for all the prepared Devices. It was found that cobalt grafting led to an increase in the intensity of the top of the trend (200) and its relative stability relative to the top of the preferential direction in the X-ray diffraction pattern, while there is a discrepancy in the values of the grain size with an increase in the proportion of cobalt grafting, as the results of the (FTIR) assays showed the emergence of the two chemical bonds (Ni-O) and (Co-O) which appear in the wavelength range (400-500 nm).

Keywords: Nickel Oxide (Nio), Cobalt (Co).

DOI: 10.9756/IAJSE/V9I2/IAJSE0919
Received: 25 March 2022/Revised: 29 April 2022/Accepted: 31 May 2022/Published: 30 June 2022

Introduction

At the beginning of the nineteenth century, researchers focused on studying semiconductors because of their good Characteristics such as changing their conductivity with heat, light and magnetic field. Because of these Characteristics, semiconductor materials have been of great importance in technological applications (1). Today, the study of deposited materials in the form of Micro Devices is one of the appropriate means to know many of their physical and chemical Characteristics, whose Characteristics are difficult to obtain in their natural form (1μm) [1].

Micro Devices physics is one of the important branches of solid-state physics, which crystallized and became a stand-alone branch. Micro Devices technology is one of the most important technologies that contributed to the development of the study of semiconductors, especially transparent conductive oxides [2].

Transparent carrier oxides are one of the basic materials used in the manufacture of Micro Devices, as the latter has attracted the attention of many researchers through its contribution to the development of several industrial and research fields, including the field of electronics, optoelectronics, batteries, reagents and photo catalysts [3]. The most important characteristic of (TCO) electrical conductivity and high transparency in the visible field of light, which is a compound semiconductors of metal combined with oxygen, that is, they are oxide semiconductors such as (ZnO, NiO, SnO_2), where most of the uses of transparent carrier oxides were In the form of Micro Devices prepared by different methods [4,5].

As a result of scientific development, Micro Devices deposition methods have developed and become highly accurate in determining the thickness and homogeneity of the devices [6]. As the methods of deposition were numerous, and each method had its own peculiarities and advantages to fulfill the purpose for which it was used [7].

Nickel oxide (NiO) is one of the important transparent conductive oxides, because it possesses unique and distinct optical, electrical and magnetic Characteristics, which qualify it to be an effective element in many physical applications as an antiferromagnetic material such as flat panel displays (LCD) and gas sensors and in the manufacture of lasers, filters and non-toxic coatings. Reflective, as well as can be used as electrodes in optoelectronic devices [8].

The addition of some metal ions as grafts contribute significantly and importantly to changes in physical and chemical Characteristics such as crystalline, electrical and optical Characteristics, where a group of researches worked on studying nickel oxide (NiO) as it is one of the available materials and easy to precipitate as it was grafted with several materials, including (Zn, Cu, Fe, Co), which led to the change in many of its physicochemical Characteristics [7].

Through this work, he will work to deposit Micro Devices of nickel oxide dotted with cobalt in different proportions on glass substrates, where an experimental study will be presented showing the effect of cobalt grafting on the structural, electrical and optical Characteristics of pure (NiO) Devices prepared by spraying pyrolysis technique.

Nickel Oxide (NiO)

Nickel oxide (NiO) is a semiconductor chemical compound of the family of transparent conductive oxides, known as "bunsénite", with a natural conductivity of type P [9]. Nickel oxide (NiO) exists in the form of either green or crystalline powder It is black with a crystalline structure, and it is considered a chemically stable substance and has important electrical and optical Characteristics. It is an antiferromagnetic substance. It is classified as a base metal oxide and its sources are nitrate, chloride and acetate. It is used in many technological fields such as batteries, smart windows, gas sensors and other applications [10].

The Crystal Structure of Nickel Oxide (NiO)

Nickel oxide is a chemical compound with the formula NiO and is known as nickel (II) oxide. It has a face-centered cubic CFC crystal structure, similar to that of sodium chloride [9], where both nickel and oxygen are divalent (O^{-2},Ni^{+2}) as shown in Figure (1), where one cell contains (8) atoms (4 atoms of nickel and 4 atoms of oxygen), where the locations of oxygen ions (O^{-2}) are at the vertices of the cube in addition to the centers of the faces, Nickel (Ni^{+2}) is in the center and middle of the sides of the cube, where (O^{-2}) forms a face-centered cubic cell (CFC) representing the nearest neighbor [10].

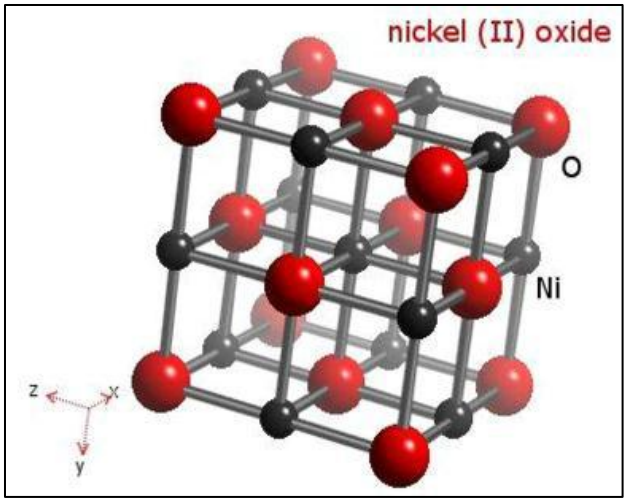


Figure 1: The Structure of Nickel Oxide [9]

and the oxygen atom occupies the position (0,1/2,0)O with respect to the reference nickel atom (0,0,0) Ni(28) and the plane (100) is a common plane consisting of 50% Nickel and 50% oxygen, and the level (111) is alternating. Face (111) is polar and therefore unstable, unlike face (100) is non-polar, so it is stable [11].

Cobalt (Co)

Cobalt is the carrier metal in group (VIII B) of the periodic table, atomic number 27, which makes its external electronic distribution as follows $3d^74s^2$, cobalt shares with iron and nickel in the magnetic property within the same group, and has one isotope Stable and it ${}^{59}_{27}Co$ and other radioactive isotopes of which only Co^{57} and Co^{60}, this metal can exist in two oxidation states (+2, +3), in addition to being characterized by its hardness and a silvery-gray color at room temperature as shown in Figure (2) [12].



Figure 2: A Sample of Cobalt Metal [13]

Characteristics of Physical and Chemical Cobalt

Cobalt is one of the important transitional chemical elements in nature. It is classified in the iron group, which includes in addition to cobalt in this group iron Fe (Z=26) and nickel Ni (Z=28). It is characterized by its high hardness, glossiness, high melting and boiling point, and many Characteristics similar to iron and nickel [13].

Solid cobalt crystallizes in compact hexagonal structure and grid size a=2.51 A°, j cobalt being 0.00023% weight of the earth's crust and its thirtieth order of prevalence and table (1) shows the physical and chemical Characteristics of cobalt.

Table 1: Characteristics of Physical and Chemical Cobalt (Co) [13]

Characteristics of cobalt metal Co	
Chemical name - chemical symbol - atomic number	Cobalt - Co - (Z=27)
Electronic distribution	[Ar] $3d^7 4s^2$
Crystal Structure	transition metal
Crystal structure	Hexagonal crystal system
molar mass	58.93319 5g/mol
half Atomic diameter	0.745 Å
Appearance	Crystalline solid
Melting point	1495°C
Electrical resistance	62.4 n□□.m (T=20°C)
Density (at room temperature)	8.90 g/cm^3
heat capacity (at T=25°C)	24.81 J/mol.k

Practical Part

Preparation of the Solution Used in the Preparation of NiO Devices Thin

Layers of nickel oxide (NiO) were deposited from a solution of nickel nitrate (Ni(NO3) 2.6H2O) with molar mass (M = 290.8 g/mol) and density (d = 2.05). A solution with a volume of (V=10 Ml) with a molar concentration (C=0.2 mol/L)) we use the following relationship.

$$m = C.M.V$$

C: Molar concentration (mol/L)

M: molar mass (g/mol)

V: volume of the solution L

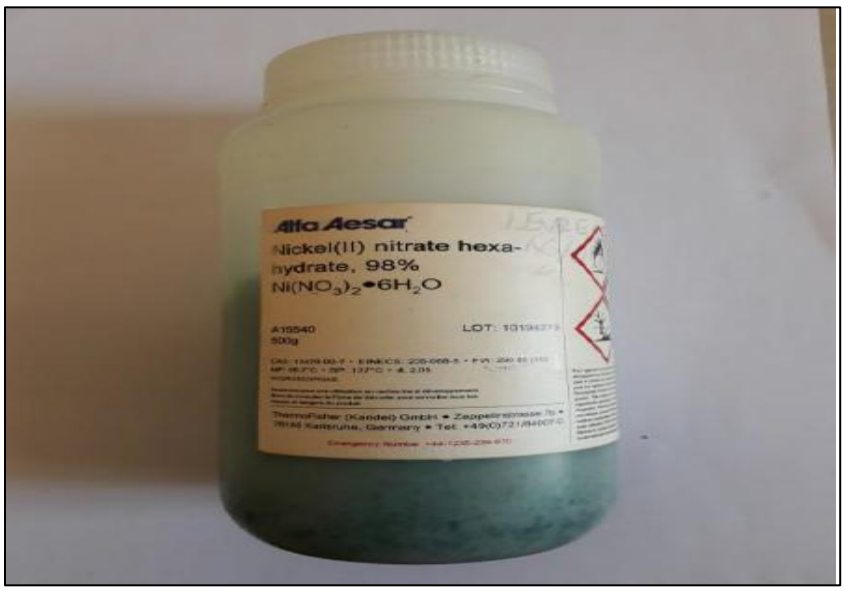


Figure 3: Nickel Nitrate Material

Preparation of the Solution for the Grafted Samples

The grafting solution was prepared from cobalt chloride powder as a source of cobalt with the formula ($CoCl2.6H_2O$) and molar mass (M=237.93 g/mol). To prepare the solution, a mass of (0.476 g) was taken using the relationship (1), and that In order to obtain a solution of concentration (C=0.2mol/L), for grafting nickel oxide with cobalt the volume ratios were applied between the grafting solution and the basic solution with volume (V1=10 mL) and concentration (C=0.2 mol/L) as shown by the following equation.

$$100=\text{at.}\% \frac{V_2}{V_1+V_2}$$

V1: The volume of the basic solution (nickel nitrate solution).

V2: The volume of the grafting solution (cobalt chloride solution).

at.%: The atomic percentage of the inoculation.

To ensure complete dissolution of both solutions, a magnetic mixer was used to mix the solution for a sufficient period of time within (30 min) to ensure No sediment.

Results and Discussion

1. X-Rays

Figure (4) shows the results of the X-ray diffraction examination of Devices of pure nickel oxide (NiO) dotted with cobalt (CO) in different proportions and prepared at a temperature of (500ºC), When analyzing these curves, the locations of the peaks that appear Sharply when beams of these rays are shone at different angles on the membrane so that they can interfere constructively. Through the results of the X-ray spectroscopy (XRD) obtained, it is clear that the pure and grafted nickel oxide Devices are polycrystalline and have three distinct peaks, all of which belong to the oxide Devices. Cubic nickel CFC, which belongs to the space group (Fm3m) by conforming to the (JCPDS 47-1049), has a preferred orientation (111) for all the prepared nickel oxide Devices, in the angle domain (2θ(37.302-37.466)), which is illustrated by the texture parameter values shown in Figure (5), which were calculated from the following relationship

$$TC(hkl)=\frac{I_{(hkl)}/I0_{(hkl)}}{\frac{1}{N}\sum_N I_{(hkl)}/I0_{(hkl)}}$$

I(hkl): measured intensity

I0 (hkl): measured intensity in card (JCPDS)

N: the number of reflections In the X-ray diffraction pattern

As for the other directions (200) and (222), at the angles domain (43.072-43.291º) and (79.553-79.664º), respectively, with the appearance of a secondary phase in the grafted samples due to cobalt oxide (CoO_2) at the vector (602) corresponding to the angle (2θ=39.4º). It is clear from Figure (4) that the height of the secondary peaks increased with the increase in the percentage of doping with cobalt (Co), and this means that the dotting worked to restore the structure of the membranes.

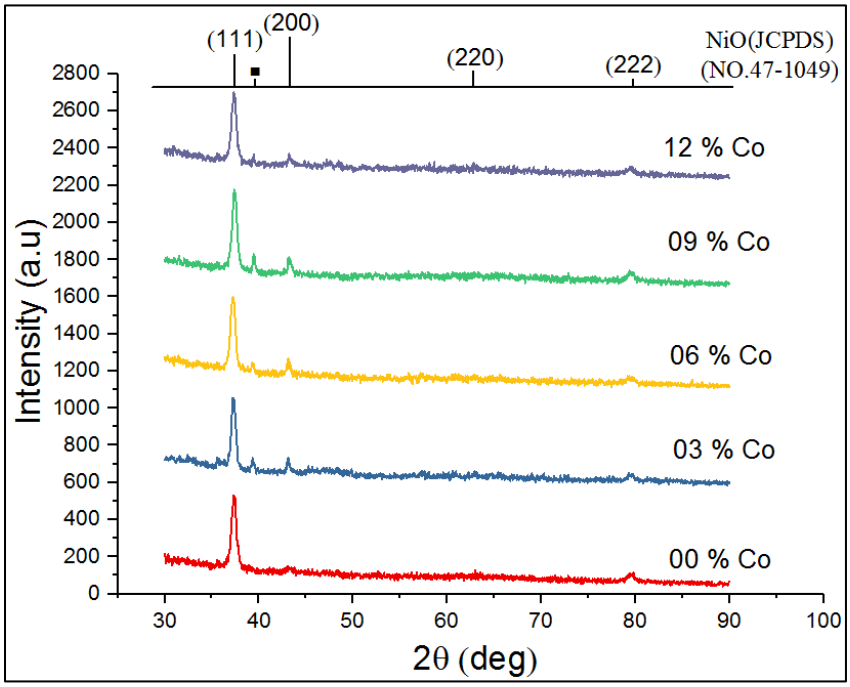


Figure 4: X-ray Yaw Scheme of Pure Cobalt - based Nickel Oxide Membranes

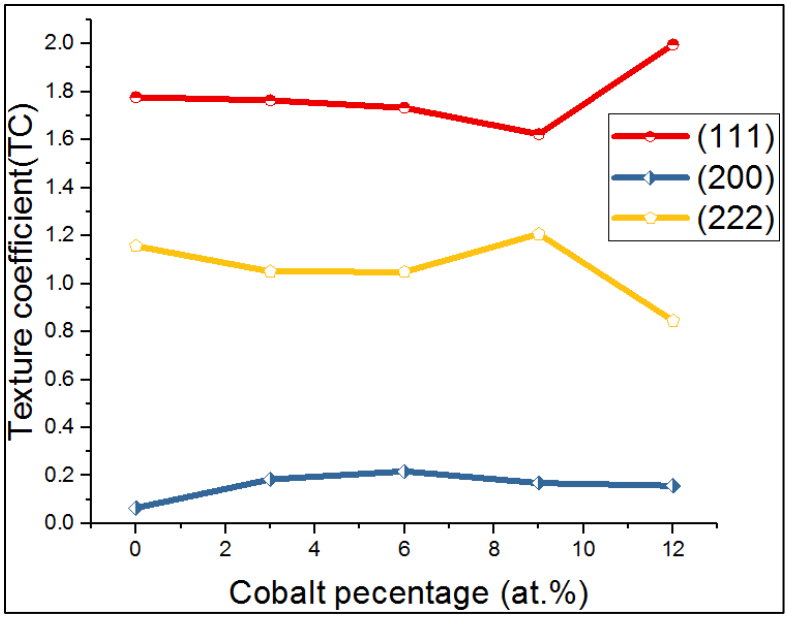


Figure 5: Shows the Changes of diffraction Angle Values in terms of Grafting Ratios

We note that the position of the peaks of the diffraction angles changes with the change in the rate of doping, which led to shifting most of the angle values towards low values, and the decrease in the angle difference ($\theta_{Co:NiO}$ - θ_{NiO}) ($\Delta 2\theta$=2) to the shift of the angle in the case of doping for all the prepared Devices.

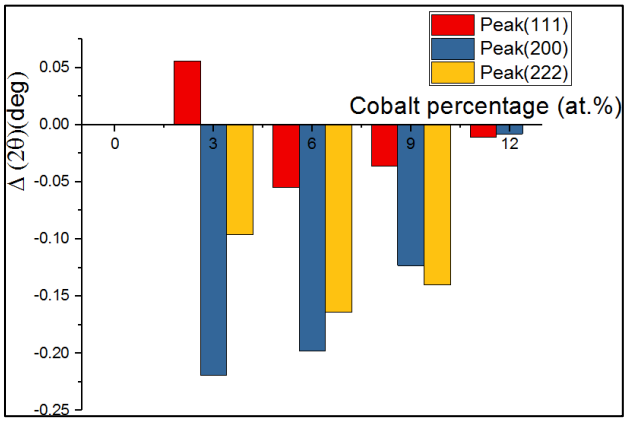


Figure 6: Δ2θ as a Function of Vaccination Ratios

2. Determination of the Crystal Lattice Constants

The distance between crystal levels (d) in all directions (111), (200) and (222) was calculated for all Devices prepared using Bragg's law through the relationship.

$$\text{Sin}\theta\ n\lambda = 2d_{hkl}$$

Where:

θ: Zorah Prague, ƛ: Wavelength

d_{hkl} : Distance between two successive atomic levels in crystal structure

n: A natural number that represents the order of diffraction

As it was found that the values of the distance between the atomic levels of pure and cobalt-doped Devices in the direction (111) are within (2.41ºA) and in the direction (200) in the range of (2.09ºA), while in the direction (222) its values are in the range of (1.205 ºA). From table (2) we notice that grafting with cobalt atoms led to an increase in the value of the lattice distance (the distance between crystal levels) (d), This change is due to the different ionic

diameters of nickel and cobalt, where (*rNi+2*=0.69 Å) and (*rCo+2*= 0.745 Å), which means the fusion of cobalt atoms in the crystal structure of the (NiO) membrane [14].

The lattice constant (a) was calculated for the nickel oxide (NiO) Devices doped with cobalt (Co) using the following relationship and then the mean value was calculated for all the Devices:

$$\frac{a_\circ}{\sqrt{h^2+k^2+l^2}} = d_{hkl}$$

We notice from Table (2) that there is a great convergence between the values of the network constant (a) obtained experimentally and the theoretical values (obtained from the JCPDS card, (ath= 4.177 Å). We notice the decrease in the value of the lattice constant (a) at the pure Devices of (NiO) (ap = 4.169 Å), which means that there is capacitive strain, i.e. compression in the crystal lattice, which is indicated by the negative value of the medium strain, which means that this Devices is subject to piston stresses. While in the case of grafted samples, we notice a slight increase in the values of the network constant for the grafted samples (3, 9, 12 at.%), while there is a significant increase for the grafted sample (6 at.%), which means that there is a pull stress, i.e. stretching In the crystal lattice of all grafted samples, which is indicated by the positive values of the medium strain, and this explains that there is a replacement of nickel ions (Ni^{+2}) with cobalt ions (Co^{+2}) and this leads to an increase in the size of the crystal.

3. Granular Size

Was calculated using the following relationship,

$$D = \frac{0.9\,\lambda}{\beta\, Cos\,\theta}$$

Where:

λ: = X-ray wavelength (λ = 1.54056)

β: The mid-highest peak-width value (FWHM) computed with the radial angle)

θ: The Bragg angle.

For all Devices prepared in all directions (111), (200), (222), as its values range between (31.894-53.672 nm). Figure (7) shows the changes of particle size (D) and network constant (a) in terms of grafting percentages. Where we notice a concordance in the change of the grain size and the network constant in the pure state, while we note that there is an inverse proportion between them in the case of the grafted samples, which means that good crystallization (increasing the values of the grain size) has led to a decrease in the value of the network constant and vice versa at different cobalt grafting rates.

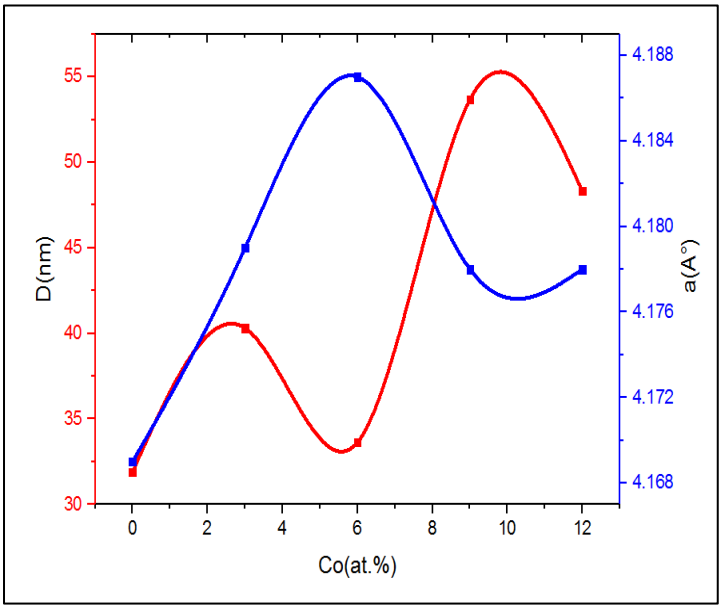


Figure 7: The Curve of the Changes of Particle Size (D) and Network Constant (a) in terms of Vaccination Rates

Table 2: Abstract of Results Obtained from X-ray diffraction (XRD) Spectra

NiO(JCPDS47-1049)		2θ	Dhkl (A°)	hkl	a(A°)	FWHM	D(nm)
		37.249	-----	111	4.177	-----	-----
		43.276	-----	200		-----	-----
		79.409	-----	222		-----	-----
NiO :Co	00%	37.466	2.400	111	4.169	0.118	31.894
		43.291	2.090	200		0.708	
		79.608	1.204	222		0.827	
	03%	37.37	2.410	111	4.179	0.108	40.312
		43.072	2.098	200		0.288	
		79.664	1.203	222		0.76	
	06%	37.302	2.411	111	4.187	0.236	33.644
		43.093	2.099	200		0.236	
		79.553	1.209	222		0.354	
	09%	37.3506	2.408	111	4.178	0.118	53.672
		43.168	2.095	200		0.118	
		79.572	1.205	222		0.59	
	12%	37.326	2.410	111	4.178	0.111	48.318
		43.283	2.094	200		0.18	
		79.597	1.204	222		0.472	

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