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Reducing Energy gap of Crystal like Nickel oxide nano structure by Added cobalt

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ABSTRACT— On silicon Si (111) substrates, different sized crystalline Nickel Oxide (NiO) and Cobalt Oxide (CoO) were electrochemically deposited. The deposition time with continuous applied current significantly altered the crystal's shape and size, and consequently its structural properties. The crystalline-like of manufactured nanostructures revealed NiO and CoO structures with distinct crystal densities and energy gaps. We investigated the properties of samples deposited using a facile and simple processing method. Highly dense NiO and CoO nanocrystals were produced on Si (111) substrates in a two-step procedure that included electrochemical deposition of Ni and Co ions followed by oxidization in a furnace under ambient oxygen. Field emission scanning electron microscopy and X-ray diffraction were used to analyze the shape and structure of the generated nanocrystals. According to the findings, grafting causes a more homogenous distribution of crystal grains, an increase in bonding, and a decrease in the energy gap value. 1.95 eV to 1.875 eV.

KEYWORDS: Nickel oxide, Cobalt oxide, crystal-like, doped

1. INTRODUCTION

Nickel Oxide (NiO) and Cobalt Oxide (CoO) have been the subject of many fundamental and applied researches due to their unique intrinsic p-type to nickel and n-type to cobalt semi-conductor material, the band gap width of approximately (3.6 - 4 e V) to nickel and (2.2 - 2.8 e V) to cobalt, and has ferromagnetic properties with low temperatures and acts as paramagnetic material in high temperatures [Both NiO and CoO demonstrated a significant amount of interest in potential applications as electrodes for supercapacitors. [3], [6], [7], catalysts [8], [9], gas sensors [10], and optoelectronic devices [11] and magnetic materials [12]. Additionally, photodiodes and dye-sensitized solar cells utilize it [13- 15]. Because NiO and CoO materials have all of the above characteristics and also display physical and chemical stabilities, their deposition has drawn increased interest. This is because these materials are particularly beneficial for optoelectronic applications. NiO and CoO thin films have been created using a variety of techniques, including chemical vapor deposition (CVD) [16], electrochemical deposition [6], atomic layer deposition [18] and pulsed laser deposition [19]. The electrochemical deposition technique, which is one of the methods mentioned above, has many benefits, including low cost, ease of setup, the ability to control the deposition conditions, the possibility of a large deposition area, and the ability to achieve these conditions without the need for a high vacuum.

This research used electrochemical deposition to create a thin coating of nickel-doped cobalt oxide. Studies have been done on the structural, optical, and morphological characteristics of nickel oxide and nickel-doped cobalt oxide layers.

2. Experimental Procedure

An electrochemical cell was utilized to deposit Ni and Co on a silicon substrate using an n-type square piece with dimensions of 1.3 cm 1.3 cm, silicon substrates of (111) orientation, (1-10 Ω.cm) as resistivity, and thickness of around (580 ± 0.25 µm), Using ultrasonic waves, the substrate was cleaned with isopropanol, methanol, and acetone. By submerging the samples in (HF) solution for 50 seconds and then washing them with deionized water, the native oxide layer was removed from the samples.

The solution of Ni was prepared using nickel chloride ($NiCl_2$), which is green crystals that have a molecular weight (23.769 $\frac{g}{mol}$) to be nickel ions source (Ni^{+2}) in deposition solution. The solution of Co was prepared using cobalt chloride ($CoCl_2$), which is Pink crystals that have a molecular weight (237.93 g/mol) to be cobalt ions source (Co^{+2}) in deposition solution. Platinum (Pt) wire was used as the anodic electrode. The current was fixed on 1.5 mA and the deposition time. This study used 0.1 M (number of moles) from $NiCl_2$ and $CoCl_2$ (powder). To obtain several moles equivalent to 0.1 M, 1.34 g of $NiCl_2$ and 1.1 g of $CoCl_2$ powder were dissolved in 50 mL of water.

Cobalt and Nickel were doped into each other at a concentration of (100 drops) Cobalt and (1 drop) Nickel, which was created with a precipitation time of 2 hours and current strength (1.5mA). The resulting Ni and nickel-doped cobalt film was inserted and set in the oven at room temperature where they underwent oxidation to form NiO and NiO/CoO films. 900 °C was maintained as the oven temperature for (1 hr). After that, let the oven come to room temperature. Using a field emission scanning electron microscope(FESEM)., the morphology of the generated NiO and the NiO/CoO films were studied. The structural measurements were made using an X-ray diffractometer. At room temperature, a spectrophotometer was used to measure the samples' predicted energy gaps from their reflectance spectra.

3. Results and discussion

Figure (1) shows the FE-SEM images. At (1µm) of cobalt oxide doped with nickel oxide and nickel oxide deposited on silicon bases by electrochemical deposition at a concentration ratio of (100 drops) cobalt oxide and (1 drop) nickel oxide created with deposition time (2hr) and current strength (1.5mA). And the annealing temperature (900 oC) for one hour. The microscopic image (1, a) of the precipitated film at a concentration of (100 drops) cobalt oxide and (1 drop) nickel oxide shows that the precipitated filmwhite in colour and distributed on the floor in the form of a structure A tree with a homogeneous distribution of grains and their interdependence and be large in size due to the grafting process. As for Figure (1,b), it is noted that the tree structure decreases and thus decreases the granular size and increases the overlap between the granules because it is a non-grafted material.

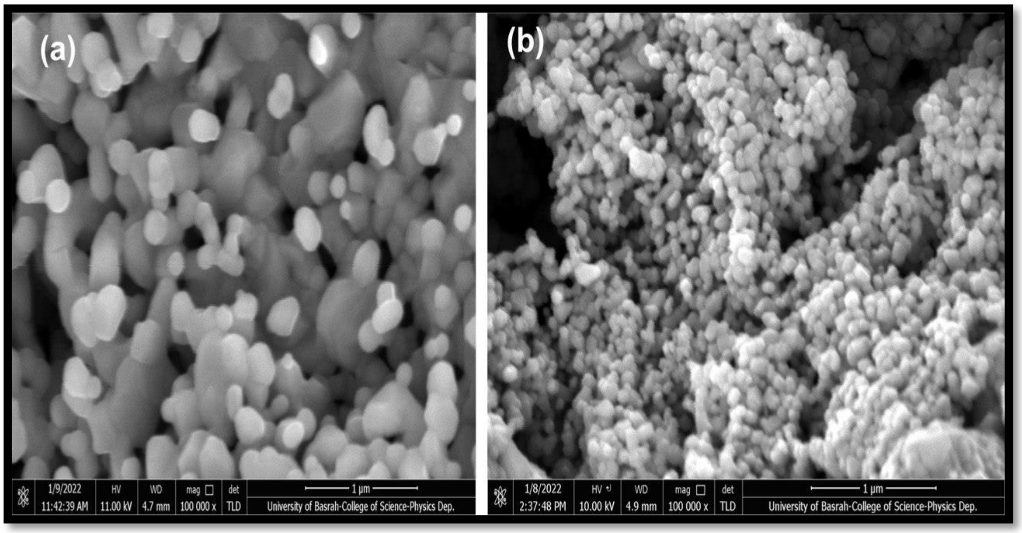

Fig. 1: FE-SEM images of nanostructures deposited for (a) NiO/CoO, (b) NiO

Figure (2) shows the X-ray spectrum of cobalt oxide doped with nickel oxide and nickel oxide placed on silicon bases using the electrochemical deposition method at a concentration ratio of (100 drops) of cobalt oxide and (1 drop) of nickel oxide prepared with deposition duration (2hr) and intensity. annealing point (900 oC) and current (1.5 mA) for one hour. We can see from Figure (2, a) and the international card (ASTM) number (00-047-1049) that the X-ray diffraction of the precipitated film has a polycrystalline cubic structure, with the best crystalline directionality (111) at angle $2\theta = 37.24°$ and (100) at angle $2\theta = 43.2748°$ and some small peaks and zigzags that are cobalt oxide. Figure (2,b) shows the X-ray diffraction of the nickel oxide film deposited on the silicon floor, where we note that the cobalt oxide film has a polycrystalline structure. And of the cubic type (Cubic) with the best crystal directivity (111) at the angle $2\theta = 37.24°$, which has a decrease in intensity, and (100) at the angle $2\theta = 43.2748°$, which has a clear increase in the intensity of the top. These peaks are due to several factors, including the grafting material, which has a clear effect on the material and the time of the deposition process, which leads to an increase in the intensity of the X-rays and the absence of the phase of the peaks of the cobalt oxide as in Figure (2,b), as well as the annealing process, which leads to an increase in the diffraction intensity as a result of an increase in Film thickness and improves crystal structure because it reduces the amount of touch Interfacial lesion between the molecules of the formed membrane, thereby making the membrane more cohesive and less porous.

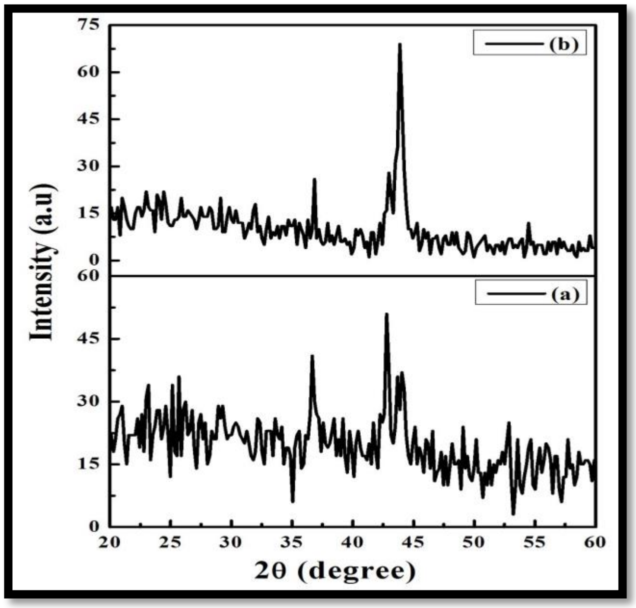

Fig. 2: XRD pattern of nanostructures deposited for (a) NiO/CoO, (b) NiO

Fig. 3 Determination of optical band gaps of semiconductor thin films by using reflectance measurements according to the equation [20], [21]

$$(\alpha h\nu)^2 = [h\nu\{ln\left(\frac{R_{max.} - R_{min.}}{R - R_{min.}}\right)\}]^2$$

R, Rmax. And Rmin. are reflectivity of the sample, maximum reflectivity and minimum reflectivity, respectively. Figure (3) represents the relationship between the optical energy gap and the reflectivity values, to calculate the value of the energy gap these values are changeable with the properties of nickel oxide Nano structure due to distortion. The optical band gap has been calculated for samples where the values of tangent and energy intersect, as in figure shows, the change in the optical gap band was caused by the difference between nickel oxide structures and its density on silicon; there was a noticeable change in particles size according to distortion note that difference in the optical gap band was small From 1.875 eV to 1.95eV. Caused by the crystal structure and it's affected by the base type and the homogeneity degree of the material lattice parameters with base lattice parameter the deposition has been applied on it also secondary transfers. At the same time, all values are closed to nickel oxide energy gap values which have been reviewed in this research.

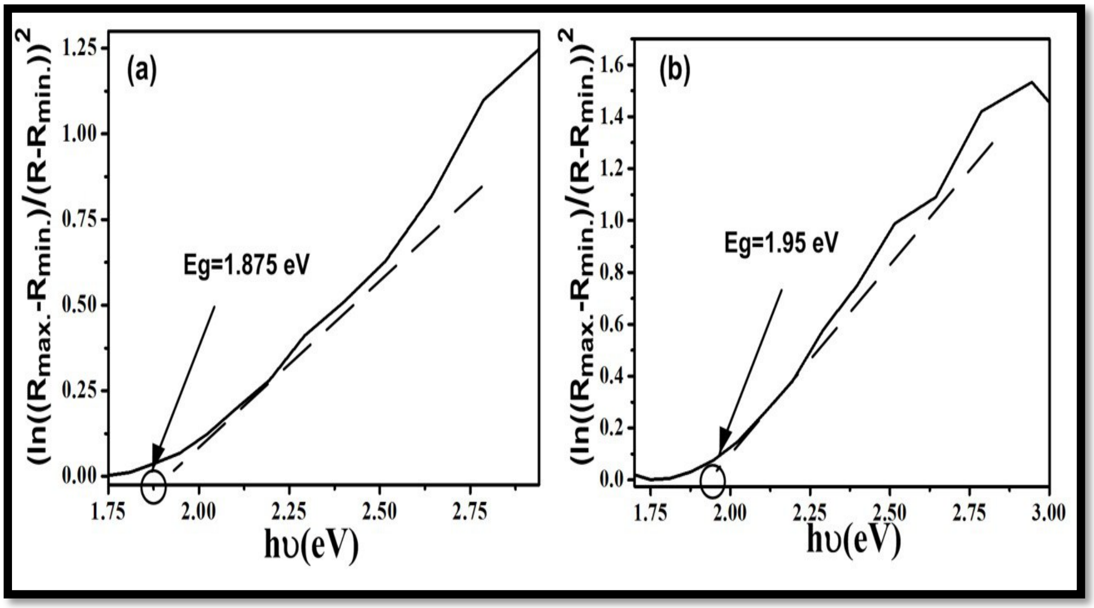

Fig. 3: Energy band gap of nanocrystals deposited for (a) NiO/CoO, (b) NiO

4. Conclusion

Three-dimensional nanostructures were produced on Si (111) substrate using electrochemical deposition (ECD). A huge substrate area can be covered while still producing high-quality crystal-like NiO nanostructures. Crystal size and density had a substantial impact on the UV detection of NiO, which had an impact on choosing the ideal deposition time. Our findings demonstrated that distortion had a significant role in determining the various crystal sizes and densities of NiO nanostructures of various lengths and diameters fabricated using (the ECD) method. According to the distortion, the sample's XRD spectrum displayed two peaks with varying strengths. The lattice is under stress, as seen by the shift in this dominating peak. We saw that distortion had a significant impact on the NiO that had been produced.

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