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Structural, Optical And Electrical Of Nickel Oxide Thin Films Deposited By Spray Pyrolysis

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The NiO thin films were prepared by spray pyrolysis method on glass substrate at 500 °C with various deposition rates (film thickness). The structural, optical and electrical properties of nanostructures NiO thin films were investigated by study the influence of deposition rate on. NiO thin films were observed a nanocrystalline a cubic structure with a strong (111) preferred orientation, it is only phase was observed in all deposited films. The minimum value of crystallite size (15.8 nm) was measured of deposited film with 50 ml. The average transmittance is about 75 % was observed in all NiO thin films. The NiO thin films have a verity in the band gap energy from 3.37 to 3.55 eV because the effect of deposition, the minimum value was found at 70 ml, this condition have a lowest Urbach energy. The NiO thin film elaborated with 70 ml has a minimum electrical resistivity was 0.152 (Ω.cm). The NiO thin films sprayed with 50 and 70 ml have good structural, optical and electrical properties.

Keywords – Nickel oxide, Thin films, Spray pyrolysis, Optical gap energy, Urbach energy.

1- Introduction

Nickel oxide (NiO) is a p-type semiconductor of semiconducting material with optical band gap was varied between 3.6 to 4 eV [1]. In the latest research, the NiO is forming of nickel metal and oxygen element, it was found in the cubic structure with lattice parameter (a= 0.4816 nm) [2]. NiO is one of the most important oxide materials due to its excellent chemical stability and durability, low toxicity, large span optical density, low cost and good thermal stability [3]. NiO was developed as thin films to be used as a gas sensing due to their good optical transparency and good electrical conductivity [4.5]. The use of NiO thin films in the detection of toxic gases has a role in improving the physico-chemical properties, by researching how to prepare and any possible method. Gavale et al. [6] studied the physical properties of nanocrystalline NiO thin films prepared by spray pyrolysis technique, where investigated the influence of film thickness on the structural, morphological and optical properties of nanocrystalline NiO films, they found that the crystallinity and the morphological properties were increased with increasing the film thickness, also obtained a good transmission in the visible region is found to be 70% with optical band gap found to in the range of 3.48 eV to 3.53 eV.

However, the NiO thin films but were used in various applications due to the simplicity of synthesis can be investigated in solar cells [7], chemical sensors [8], photodetedors [9], electro chromic minors [10], organic light emitting diodes [11] , UV detectors [12], vans parent diodes [13] , and defrosting windows [14]. NiO thin films can be prepared by various methods likely molecular beam epitaxy (MBE) [15], electrochemical deposition [16], chemical vapor deposition [17], sol-gel process [18], reactive evaporation [19], pulsed laser deposition (PLD) [20], magnetron sputtering technique [21] and spray pyrolysis [22]. The spray method was used for technological applications because it is one of the most important techniques to deposition a large-scale production. The prepared the thin films by this method have a good adhesion mechanical, and good electrical conductivity; also it has a high optical transparency and magnetic properties of nanostructures NiO.

The main objective of this work is to obtain a semiconductor as NiO thin films with high crystalline structure, good optical and electrical properties. In the present work, nanostructure NiO thin films were investigated, which are elaborated by spray pyrolysis method, the NiO was heated on glass substrate at a deposition temperature of 500 °C with various deposition rates of 10, 30, 50 and 70 ml. the effect of deposition rate on structural, optical and electrical properties were investigated in the section of results and discussion.

2- Experimental

NiO solution was prepared by dissolving 0.06M ($Ni(CH_3COO)_2$, $4H_2O$) in the solvent containing equal volume absolute ethanol solution (99.995%) purity, the stabilization was carried with stirring the NiO solution for 90 min and addition of drops of HCl solution. The final solution was stirred and heated at 50 °C for 90 min to good transparent solution. The preparation was performed on glass substrates by spray pyrolysis method with heating at 500 °C. The NiO thin films were elaborated at 500 °C in air with various deposition rates of 10, 30, 50 and 70 ml.

The crystalline structure of sprayed final films was carried by X-ray diffraction (XRD, Bruker AXS-8D) with CuKα radiation (λ = 0.15406 nm) by varying the scanning range of (2θ) from 20° and 70°. The transmittance and absorbance of the spayed NiO films was investigated in the wavelength range of 300–900 nm by spectrophotometer (SHUMATZU 1800). Finally, the electrical resistivity was measured by the four point’s methods.

3- Results and discussion

3-1-Structural properties of NiO thin films:

The X-ray diffraction (XRD) spectrum of the deposit NiO thin films by spray pyrolysis is shown in Figure (1). The NiO thin films were obtained at various deposition rates are 10, 30, 50 and 70 ml. The XRD spectrum of sprayed NiO thin films was matched the structure of NiO thin films is cubic structure with JCPDS (No. 73- 1519) [20]. From this data can observed a only diffraction peak at 2θ = 37.6°, which is related to the plan of (111). All the spectra's of NiO thin films having one peak with higher in the sharper indicating that the obtain NiO thin film has a nanocrystalline structure. The good results were found for the film prepared with 50 and 70 ml due to the increase in the FWHM of the peaks. However, the preferred orientation is perpendicular with (111) plane. The crystallite size of all deposited NiO thin films was calculated by the Debye-Scherrer formula [23]:

$$G = \frac{0.9\lambda}{\beta\cos\theta} \qquad (1)$$

where G is the crystallite size, λ is the wavelength of X-ray (λ = 1.5406 A°), β is the FWHM and θ is the half diffraction angle.

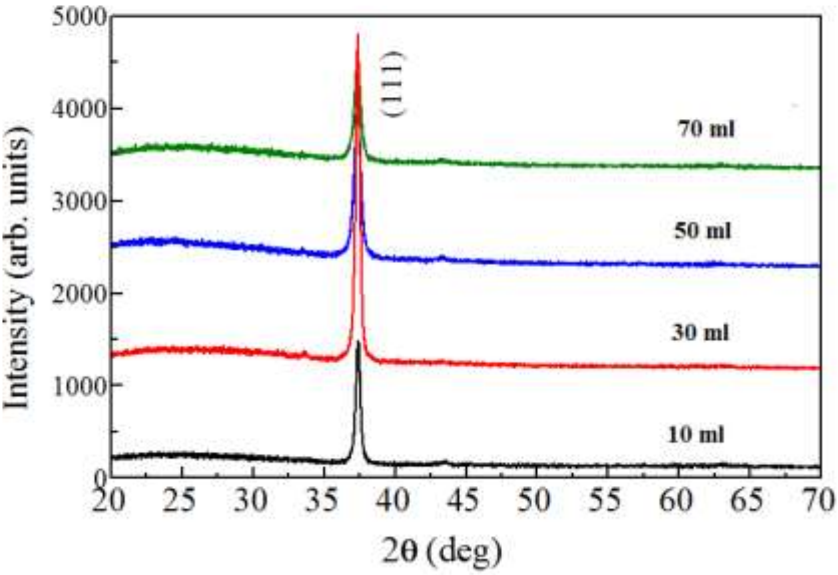

Figure (1) : X-ray diffraction spectra of NiO thin films at different deposition rates.

Reported in the Figure (1) as a function of deposition rate the variation of the crystallite size and the diffraction angle of (111) diffraction peak. The crystallite sizes were stabilized at 10 ml and 30 ml of are taking two values 23.9 and 24.6 nm, respectively. Then decreased to minimum value was found at 50 ml of deposition rate it is 16.1 nm. The decrease in the crystallite size of NiO thon films was indicated to improve of crystalline structure. However, the decrease of diffraction angle with decreasing of crystallite size showed that the existence of sufficiently thicker films in less strained (or more relaxed) state.

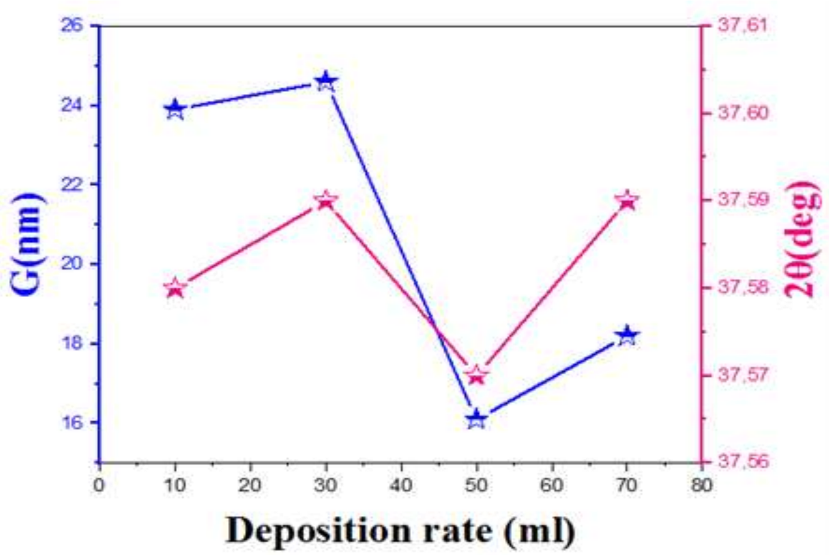

Figure (2) : The variation of crystallite size and diffraction angle as a function of deposition rate in NiO thin films

3-2-Optical properties of NiO thin films:

The Optical properties of NiO thin films deposited at various deposition rates were performed by measuring the transmittance and absorbance in the wavelength region 300 to 900 nm, it are shown in Figure (3) . Can see that the height transparency of the NiO thin films in visible region with an average transmission is about 75 %, so that the films exhibit high transparency by comparing with original nature, it is found by various literatures in the range 30 to 50% [24,25]. The region of the absorption edge was observed when the transmission was decreased, which is related transition between the valence band and the conduction band it is located between 310–380 nm. The inset of Figure (3) was present the variation of absorbance data of NiO thin films, the absorption edge shifts was observed clearly at wavelength shorter than 390 nm. The absorption edge shifts of NiO thin films were decreased with increasing the deposition rate. As can be note, the optical property of NiO thin films is affected by deposition rate.

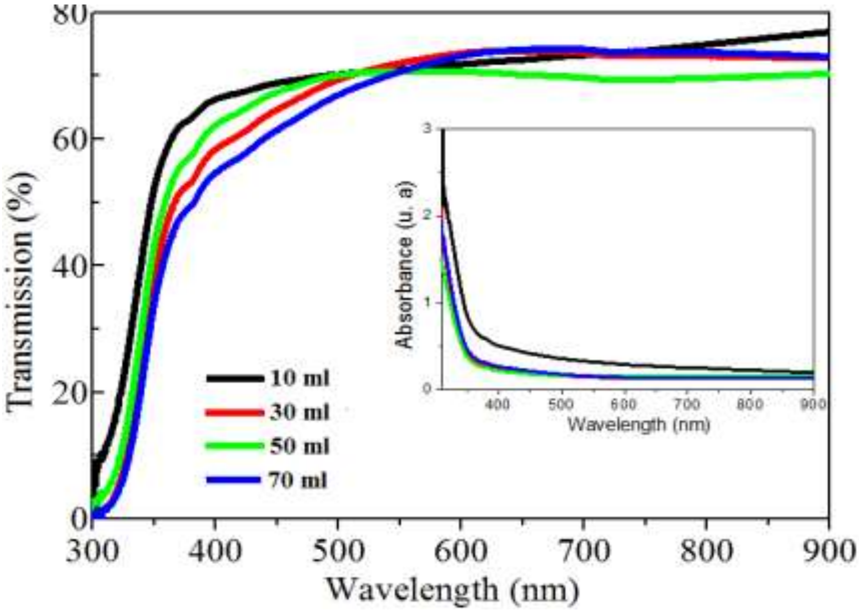

Figure (3): Transmission spectra of NiO thin films as a function of deposition rate, the inset present the absorbance of the thin films..

The role of deposition rate on transmission of NiO thin films was clearly observed on the layer quality. But the absorption edge of NiO film was observed to red shift can be explained by the changes in the optical band gap. So that absorbance and the optical band gap energy E_g of NiO thin films were determined by the following relations [3,26]:

$$A = \alpha\, d = -\ln T \quad (2)$$

$$(Ah\upsilon)^2 = C(h\upsilon - E_g) \quad (3)$$

where A is the absorbance, d is the film thickness; T is the transmission spectra of thin films; α is the absorption coefficient values; C is a constant, $h\nu$ is the photon energy ($h\nu = \frac{1240}{\lambda(nm)}(eV)$) and E_g the band gap energy of the semiconductor. However, the disorder or Urbach energy (E_u) also was determined by the expression follow [27]:

$$A = A_0 \exp\left(\frac{h\upsilon}{E_u}\right) \quad (4)$$

where A_0 is a constant $h\nu$ is the photon energy and E_u is the Urbach energy, the Urbach energy was used for characterize the order of the defects.

The variation of optical band gap and Urbach energy was calculated as a function of deposition rate, it is presented in the Figure (4). The band gap energy was observed a smaller than 3.5 eV, it is change and decreased with increasing of deposition rate from 3.55 to 3.37 eV of 10 to 70 ml, respectively. The decrease in the optical value of NiO thin films can be explain by effect of quantum confinement due to the diminution in the crystallite size of NiO thin films (see Figure (2)). As can be seen in Figure (4) that the Urbach energy was increases from 10 to 50 ml, and decrease to minimum value was found at 70 ml is 300meV. This is can be related by the diminution of the crystallite size (see Figure (2)).

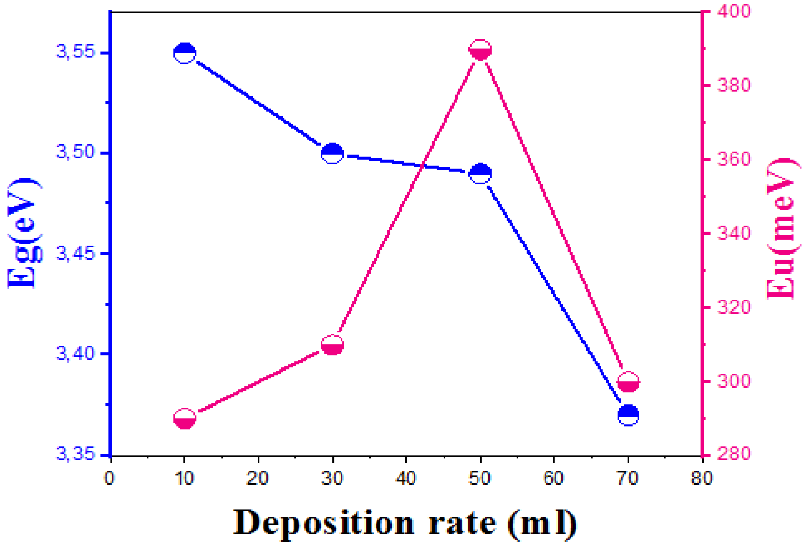

Figure (4): The variation of optical band gap E_g and Urbach energy E_u of NiO thin films with deposition rate.

3-3- Electrical properties of NiO thin films:

Figure (5) shows the variation as a function of deposition rate of the electrical resistivity of NiO thin films. The deposition rate was play an important parameter in prepared the NiO thin films. The variation of electrical resistivity was measured with the increase in the deposition rate (increase in the film thickness). These variations are rapid decreases to minimum value at 70 ml is 0.152 Ω.cm. The decrease in the resistivity of NiO films can be explained by the diminution of defects, which was related by the decreasing in the Urbach energy (see Figure (4)).

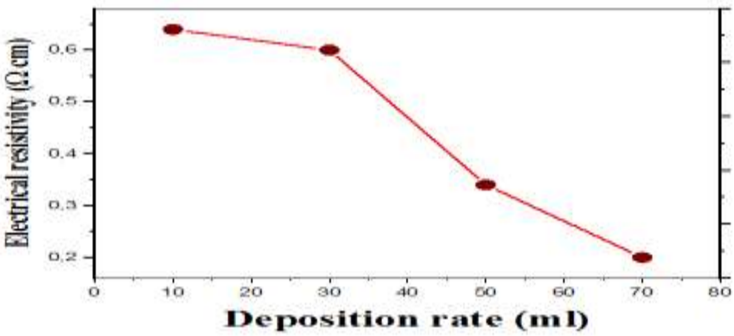

Figure (5): Electrical resistivity of NiO thin films at different deposition rate.

Conclusion

In this study, we reached several results, namely the structural properties of zinc oxide And we proved after the use X-ray diffraction rat of NiO the variation of the crystallite size .it is stabilized between 30ml and 50ml in this en range of values are taking 23.9 and 24.6 nm **and the value of deposition rate is 16.1 nm at 50 ml** , and the optical properties of nickel oxide precipitation compounds, in terms of measuring transmittance in the wavelength axis between values 300 and 900 in this visible range, the transmittance is high, reaching 70%, and this percentage is higher than the original percentages obtained previously, the sedimentation coefficient affects the permeability of thin films of this chemical compound, as a shift in the absorption edge towards the red color was found, and this was explained by the instability of the optical band gap. The Erbach energy was studied as a function of the deposition rate and the change in the optical band gap. It was found that the optical band gap in this case does not exceed 3.5 eV and it changes as a function of the deposition rate. the optical value of the thin films decreases due to the decrease in the total crystal size. for the electrical properties of nickel oxide, the electrical resistance changes with the thickness, as the electrical resistance and Erbach energy decrease with increasing layer thickness.

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