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Effect of Thickness on Optical Properties of Nickel Oxide Thin Films

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Abstract: *A thin film of Nickel Oxide (263.15, 144.9, and 90.9) nm was deposited on an FTO glass substrate using the spin coating process. Absorption coefficient, extinction coefficient, refractive index, and optical energy gap were determined using absorbance spectra collected with a UV-VIS spectrophotometer. The absorbance spectrum of all samples ranges from 200 to 400 nm, and absorbance increases with thickness, with a high absorbance value at 236 nm corresponding to photon energy 5.254 eV. The absorption coefficient ranges between* 1.9×10^7 *and* 8.6×10^6 *cm-1 for all samples. As the thickness decreases, the value increases, indicating a direct electronic transition. The maximum refractive index for all samples is 1.0222. The obtained optical energy gap value is between (3.526 and 3.358) eV, and the optical band gap decreases as the thickness of the thin film increases.*

Keyword: Nickel Oxide, Thin Films, Refractive Index, absorption coefficient and optical energy gap.

Introduction

A thin film is a layer that extends endlessly in two dimensions but is constrained in the third direction, with a thickness ranging from several nanometers to a few micrometers [1]. Thin film cells have been popular since the late 1970s, when solar calculators powered by a thin strip of amorphous silicon were introduced to the market. It is now available in big modules for application in sophisticated building integrated installations and vehicle charging systems [2, 3]. Thin films have numerous advantages, including size reduction, adjustment of material surface properties (reflection, absorption, hardness, abrasion resistance, corrosion, and electrical behavior), cost savings, and device miniaturization [4,5]. Thin Film Deposition technology is often recognized as the primary key to the development of electronics such as computers, as all microelectronic solid-state devices are built on material structures generated by deposition techniques. Thin film technology is distinguished by excellent stability and accuracy of electronic components and devices, as well as a level of reliability that is not economically attainable with other technologies [6].

Nickel oxide (NiO) is a desirable substance because of its chemical stability [7]. It is a semiconductor with cubic crystal structure. NiO has a wide inherent band gap of around 3.6 eV [8]. It exhibits remarkable optical, electrical, and magnetic properties. It is a viable candidate for a variety of applications, including smart windows, gas sensors, catalysts, anode materials in Li-ion batteries, and nanoscale optoelectronic devices such as electrochromic displays [9]. Furthermore, nanocrystalline NiO powder exhibits super paramagnetism, which can be employed as a medication delivery and MRI (magnetic resonance imaging) agent. NiO nanostructures have been synthesized using a variety of processes, including sol-gel, co-precipitation, hydrothermal, solvothermal, anodic arc plasma, sonochemical, microwave pyrolysis, thermal decomposition, micro-emulsion, and chemical precipitation. In this study, the optical characteristics of nickel oxide generated via sol-gel technique were investigated using a UV-VIS spectrometer.

Method

Nickel oxide thin films were prepared by spraying a 0.1 M solution of nickel nitrate of doubly distilled water onto the pre-heated amorphous glass substrates kept at (390˚C ± 10˚) C. Iron oxide thin films were prepared by spraying a 0.1 M solution of ferric nitrate of doubly distilled water onto the pre-heated amorphous glass substrates kept at (390˚C±10˚C). Film thickness was measured by using the weight difference method considering the substrate surface area and the density of the bulk nickel oxide. As the density of thin films was certainly lower than the bulk density, the actual film thickness would be larger than the estimated values the thickness of the thin film. The optical characterization of the prepared thin films was calculated from absorbance spectrum that obtained using UV-VIS spectrometer.

Results and Discussion

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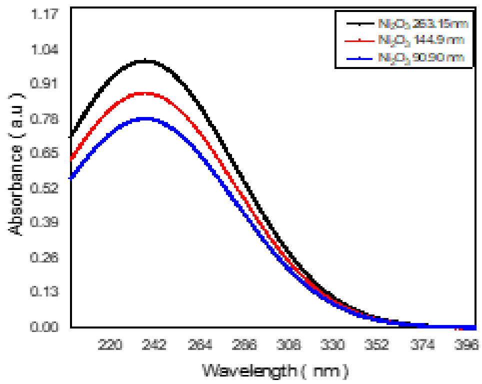

Fig (1) absorbance of Nickel Oxide samples in different thickness

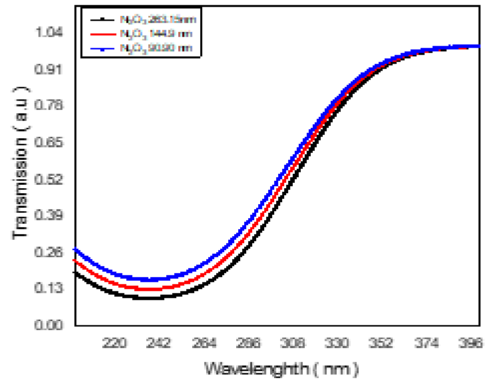

Fig (2) transmission of Nickel Oxide samples in different thickness

The absorbance spectrum of nickel oxide thin film samples in different thickness (263.15, 144.9 and90.9) nm were obtained using UV-VS min 1240 spectrophotometer and then used to calculate some optical properties.

Figure (1) depicts the absorbance results of nickel oxide thin film samples; the absorbance curve shows a rapid increase in absorption at wavelengths 236 nm, with a photon energy of 5.254 eV, as thickness increases in the UV area. The transmission is the opposite behavior of absorbance; the transmissions of all samples of Ni_3O_2 were as shown in fig (2); it was noticed that the transmissions value increases when the thickness decreases.

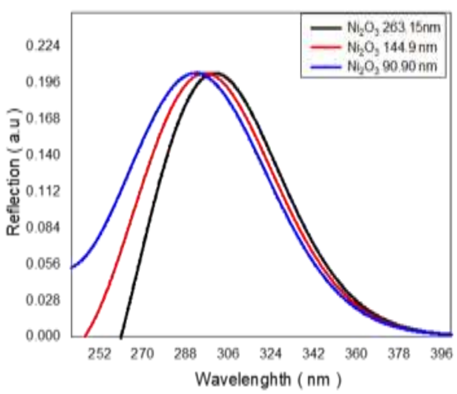

Fig (3) reflection of Nickel Oxide samples in different thickness

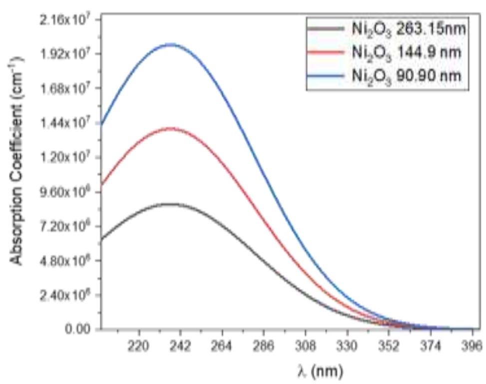

Fig (4) absorption coefficient of Nickel Oxide samples in different thickness

Figure 3 shows the reflection for nickel oxide thin film samples. The greatest reflection value spanned from 290nm to 305nm, with a blue shift as thickness decreased, and the samples became mirrors in this range. The absorption coefficient (α) of nickel oxide thin film samples was calculated using the equation $\alpha = ((2.303 \times A))/t$, where (A) is absorbance and (t) is optical length in the samples [11]. Fig (4) The plot of (α) with wavelength (λ) shows that the value of $\alpha = 1.9\times10^{7}$ cm^{-1} for Ni_2O_3 (90.9 nm) thin film thickness samples at 236 nm when the Ni_2O_3 (144.9 nm) thin film thickness sample equal 1.4×10^{7} cm^{-1} at the same wavelength, but the Ni_2O_3 (263.15) nm thin film thickness sample equal 8.6×10^{6} cm^{-1} at the same wavelength. This means that the transition must correspond to direct electronic transition, and the properties of this state are important. Additionally, the value of (α) for nickel oxide thin film samples increased while thickness samples declined.

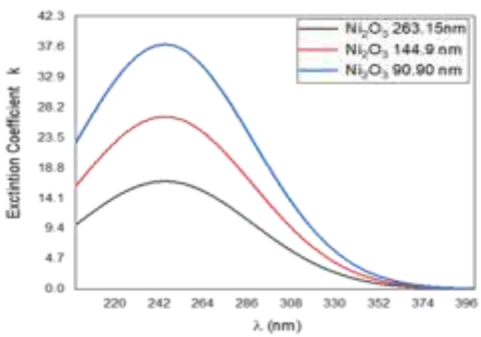

Fig (5) extinction coefficient of Nickel Oxide samples in different thickness

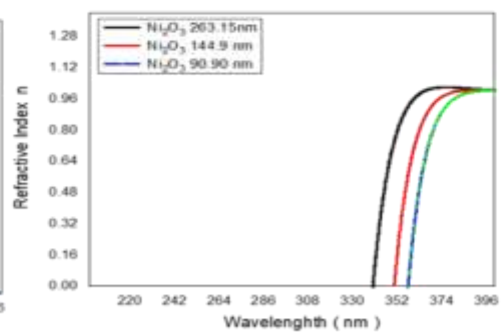

Fig (6) absorption coefficient of Nickel Oxide samples in different thickness

Extinction coefficient (K) was calculated using the related $k = \frac{\alpha\lambda}{4\pi}$ [12]. The variation at the (K) values as a function of (λ) are shown in fig (5) for nickel oxide thin film samples, the obtained value of (K) at the 236 nm wavelength was depend on the samples thickness , the value of (K) for Ni_2O_3 (90.9 nm)thin film thickness samples equal 38 while for Ni_2O_3 (144.9 nm) thin film thickness sample equal 27 and for Ni_2O_3 (263.15 nm) thin film thickness sample equal 17 , the extinction coefficient (k) decreased when the thickness increased . The refractive index (n) is the relative between speeds of light in vacuum to its speed in material which does not absorb this light. The value of n was calculated from the equation $n = \left[\left(\frac{1+R}{1-R}\right)^2 - (1 + k^2)\right]^{\frac{1}{2}} + \frac{(1+R)}{(1-R)}$ Where (R) is the reflectivity [13], the variation of (n) vs. (λ) is shown in fig (6) which shows that the maximum value of (n) is (1.0222) for Ni_2O_3 (263.15nm) at wavelength (273nm).

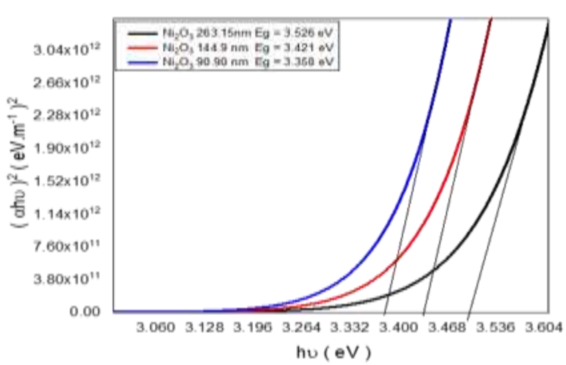

Fig (7) optical energy band gap of Nickel Oxide samples in different thickness

The optical energy gap (Eg) has been calculated by the relation $(\alpha h\upsilon)^2 = C(h\upsilon - Eg)$ where (C) is constant[14]. By plotting $(\alpha h\upsilon)^2$ vs photon energy (hυ) as shown in fig.(7) for all samples of Ni_2O_3 thin films . And by extrapolating the straight thin portion of the curve to intercept the energy axis, the value of the energy gap has been obtained, from fig (7) the obtained value of (Eg) equals 3.526 eV for Ni_2O_3 (263.15 nm) while for Ni_2O_3 (144.9 nm) equal 3.421 eV and equal3.358 eV for Ni_2O_3 (90.90 nm), It is clear that the optical band gap decreases as the thickness of the thin film increases.

Conclusion

The thickness of nickel oxide thin films has a clear impact on optical properties (absorbance, transmission, reflection, absorption coefficient, extinction coefficient, and optical energy gap). All optical properties calculated for wavelengths ranging from 200 to 400 nm. According to the results, these thin film samples are suited for photoelectric applications.

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