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INVESTIGATING THE OPTICAL CHARACTERISTICS OF NICKEL OXIDE THIN FILMS

by

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Abstract
The optical characteristics of Nickel Oxide (NiO) thin films deposited on glass substrates via chemical bath deposition at room temperature were systematically investigated. The absorbance spectra of the films were recorded using shimadzu UV – 2030 UV-Vis spectrophotometer with high sensitivity photomultiplier tube (PMT) detector, spanning wavelength range of 300 – 1100 nm. The results showed that the films exhibited high transparency with an average transmittance of approximately 80%. The optical absorption study revealed that NiO thin film has a bandgap range of 3.5 eV- 3.8 eV and a refractive index of 1.5. Notably the reflectance of the deposited films was observed to be low across the entire measured spectrum.

Keywords: **Optical Characteristics, Nickel Oxide & Thin Films.**

Introduction
Nickel Oxide (NiO) thin film is significant in many applications in science and technology. It is a semiconducting metal oxide. Transition metal oxides like nickel oxides have found wide application in material science such as sensors (Jung – Chuan et al., 2021), efficient control of energy inflow-outflow of buildings (Shuandui et al., 2023), large scale optical switching (Xuejing et al.; 2022), transparent electrode (Yu Bai et al., 2022), Cathode materials or electrodes (Abdullah et al., 2016), anti-ferromagnetic layers (Saima et al., 2021) and solar terminal absorbers (Aref et al; 2002).

Nickel Oxide thin films are stable, strongly adherent to the substrate, mechanically hard, and resistant to moisture and acids of chemicals (Gomaa et al; 2015). Owing to its outstanding electrical, optical and electrochemical properties, a variety of applications is highly recommended for the electro chronic materials in general. These include electrical light – modulation devices, such as; non-emissive large scale displays, electrically controlled optical shutters for

heat and light modulators for windows, smart windows-photovoltaic powered electro-chronic devices (Ristoraa et al; 2002).

The most important potential commercial application of the electro chronic films would be, glazing of buildings and houses to provide dynamical control of the incoming illumination (Shuangdui, et al; 2023), and thus an energy efficient housing, lifestyle (Ristoraa et al; 2002).

Nickel Oxide is an anodic electro-chronic material, which colours upon reduction. The phenomenon of anodic coloration of nickel oxide allows potential applications of this material as a counter electrode in conjunction with tungsten oxide as working electrode in assembling electro-chronic devices. This has the advantage of increasing the optical density variation of the device, since both electrodes, colours and bleach simultaneously. Some other interesting electronic properties of NiO thin film include; its wide bandgap range of 3.6 – 4.0eV (Ezema et al; 2007), and its p-type conductivity which makes it as favourable materials for electronic device applications (Ajuba et al; 2010).

This study presents the investigation of the optical properties of chemical bath deposited nickel oxide thin film. The optical properties investigated include the Absorbance (A), and Transmittance (T) which were used to calculate` extinction coefficient (K). These optical and solid state properties and the band gap of the films were obtained from equations given by (Ezema et al; 2007).

Materials and Method

Thin films of nickel oxide (NiO) were successfully deposited on glass substrates using the Chemical Bath Deposition (CBD) method. The deposition process involved a reaction between 0.5 mole of nickel chloride hexahydrate ($NiCl_2.6H_2O$), which provided the nickel ions (Ni^{2+}), and an anomia solution. Five samples were prepared as summarized in Table 1, where the concentration of nickel chloride hexahydrate temperature (room temperature), and deposition time were held constant, while the concentration of ammonia solution was varied. Ammonium solution was added to maintain a suitable alkaline pH range (10.2 $\pm$ 0.1) in the deposition bath, facilitating the growth of NiO thin films.

Table 1: Bath Constituents for the Department of NiO Films

Samples	**$Nicl_2.6H_2O$ (mls)**	**NH_3 SOL. (mls)**	**H_2O (mls)**	**Time (hrs)**
F_1	10.00	2.00	60.00	24
F_2	10.00	4.00	60.00	24
F_3	10.00	6.00	60.00	24
F_4	10.00	8.00	60.00	24
F_5	10.00	10.00	60.00	24

This research investigates the crucial role of complexing agents in the Chemical Bath Deposition (CBD) method for preparing Nickel oxide (NiO) thin films on glass

substrates using nickel chloride hexahydrate solutions. To unlock the full potential of these materials for various technological applications, a thorough understanding of their optical properties is essential. Accordingly, this study examines key optical parameters, including absorbance, transmittance, reflectance, extinction coefficient, and refractive index to characterize the optical behavior of NiO thin films.

The Optical properties of the films were characterized using, UV – Vision spectrophotometry which involved measuring spectral absorption and reflection. The transmission and reflection spectra of the films were recorded across a broad wavelength range of 300 – 1100nm encompassing the Ultraviolet (UV), Visible (VIS), and near –Infared (NIR) regions.

The spectral measurements were performed at a scan interval of 5nm, providing high-resolution data on optical behaviour of the films.

Results and Discussion

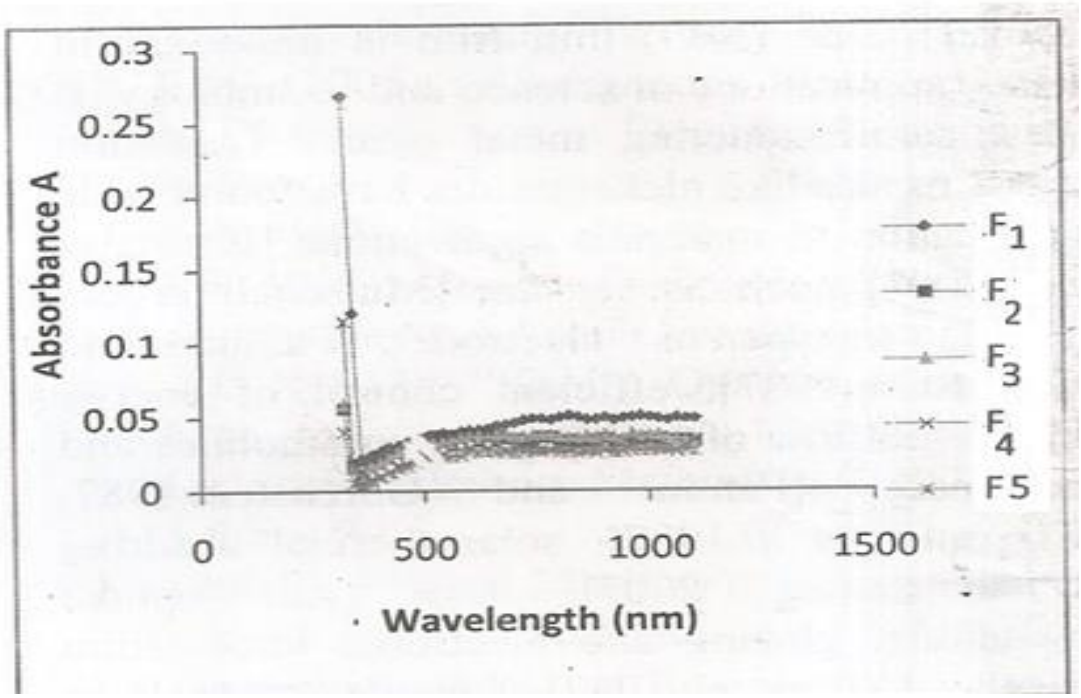

Fig. 1: Absorbance Spectra of the Grown NiOfilms Against Wavelength

Figure 1 above is the plot of the absorbance spectra of NiO thin films as a function of wavelength. The cures show low absorbance throughout the spectrum. Sample F_1, has absorbance of approximately 0.05 abr unit in the VIS/NIR region of the electromagnetic spectrum, while sample F_5 has approximately 0.025 abr unit in the same region.

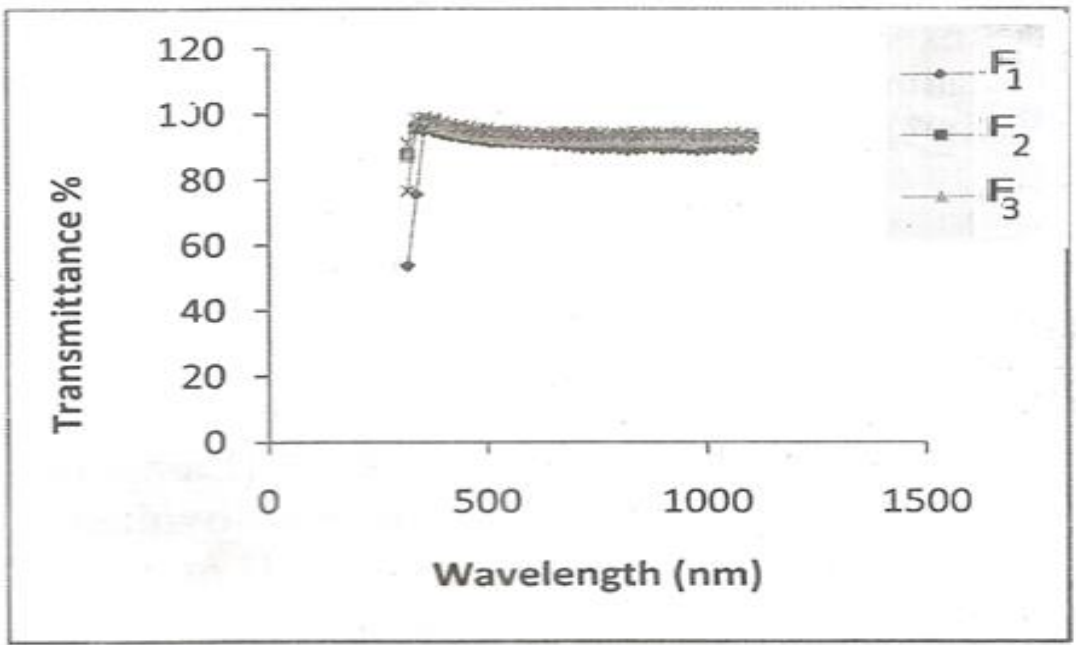

Fig. 2: Transmittance Spectra of the Grown NiO Films Against Wavelength

The transmittance is generally high for all the samples throughout the VIS/NIR region of the electromagnetic spectrum. All the samples have transmittance slightly greater than 80% throughout the VIS/NIR region of the EM spectrum. The high transmittance in the visible region makes NiO films useful for aesthetic window glazing materials and suitable for solar energy collection because if coated on the surface of the collector it will reduce reflection of solar radiation and transmit radiation to the collector fluid.

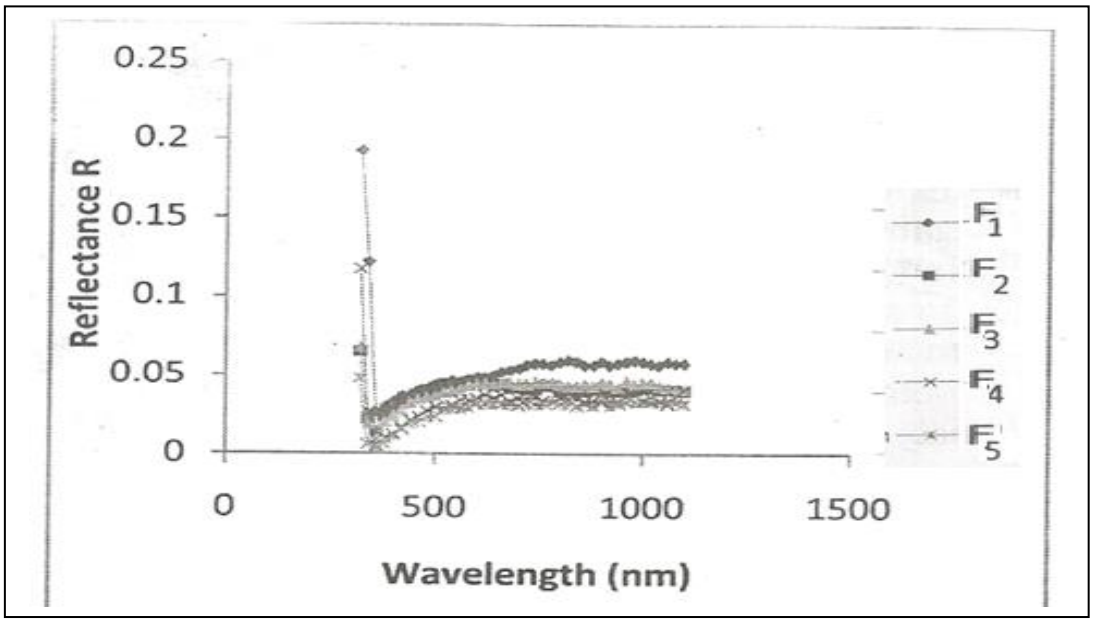

Fig. 3: Reflectance Spectra of the Grown NiO Films Against Wavelength.

Figure 3 above is the plot of the reflectance spectra versus wavelength of NiO films. Generally, all the films show a very low reflectance throughout the UV/VIS/NIR region. Sample F_1 has a value of 0.0075 abr unit in the wavelength range of 800 – 1100nm, while sample F_5 has approximately 0.025 abr unit in the same range. This decrease in the reflection is attributed to increased transmittance. With low reflectance values in the VIS-NIR region, the film is best for photovoltaic devices like solar cells as a window layer as this reduces reflective losses on the cell surface (Ezenwa and Ekpunobi, 2011).

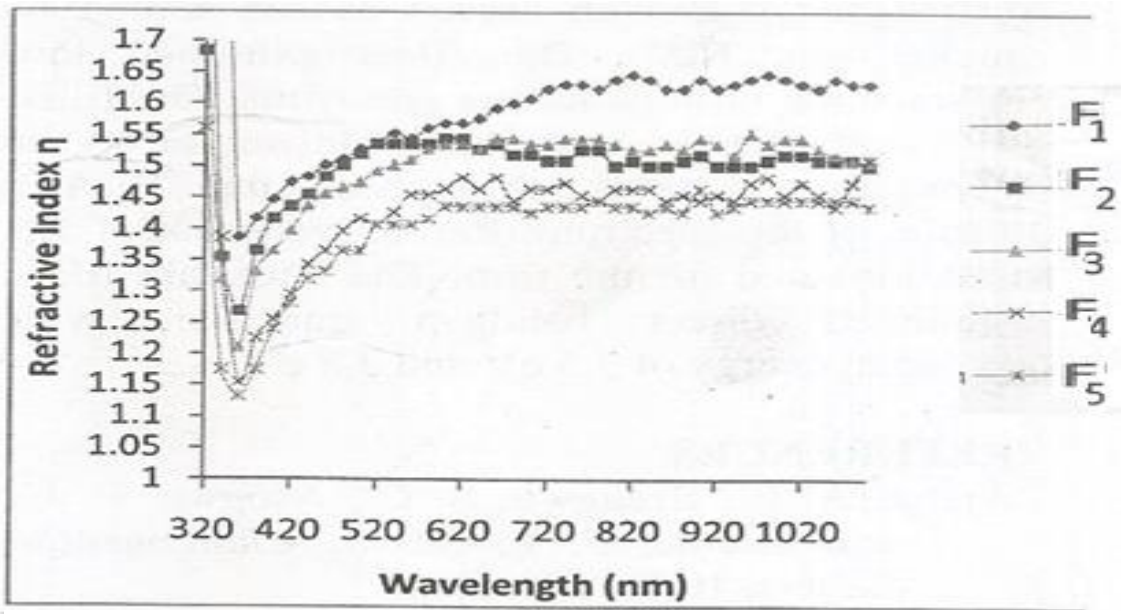

Fig. 4: Refractive Index Spectra of the Grown NiO Films Against

The figure above shows a plot of refractive index spectra versus wavelength of NiO films. The refractive index of the films is almost uniform for all the samples throughout the VIS/NIR region of the electromagnetic spectrum, revealing a refractive index of approximately 1.5 and 1.3 in the wavelength range of 700 – 1100 nm for samples F_1 and F_5respectively. This result shows that NiO has high refractive index. The high refractive index possessed by NiO films makes them suitable for use as anti-reflection coatings.

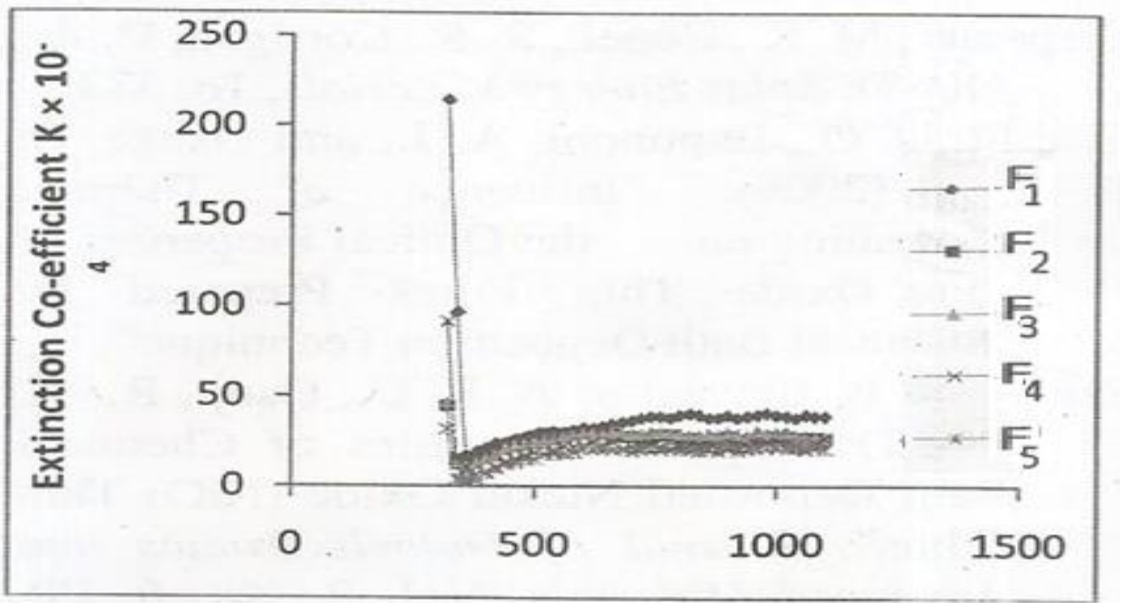

Fig. 5: Plot of Extinction Coefficient of the Grown NiO Films Against Wavelength

Fig. 5 Shows the variation of extinction coefficient with wavelength. Sample F_1 has the highest value of 50 x 10^{-4} at wavelength range of 800 – 1100nm, while sample F_5 has the lowest value of25 x 10^{-4}at wavelength range of 800 – 1100nm.

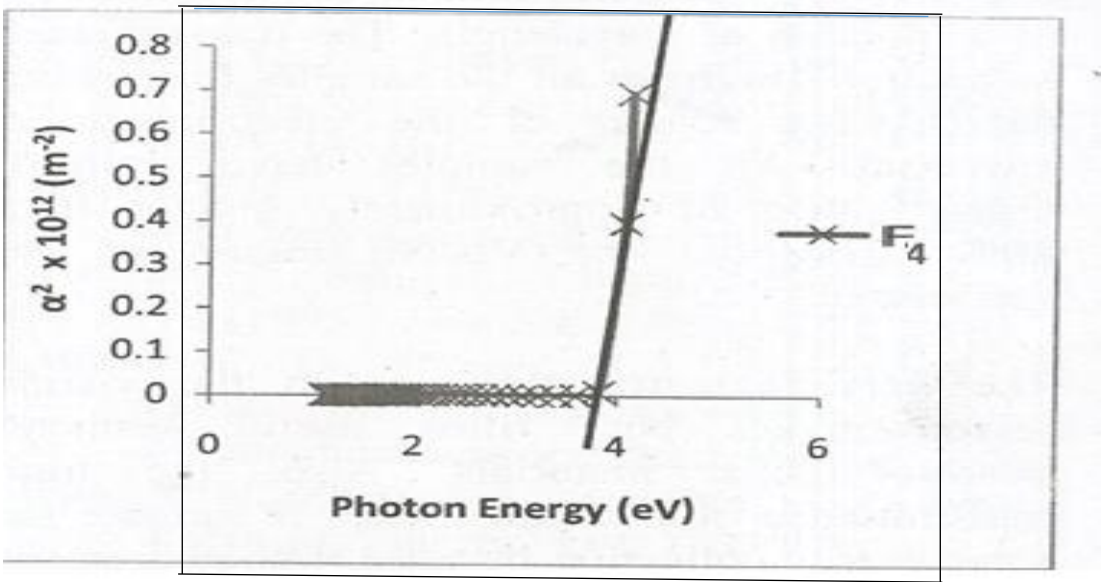

Fig. 6: Plot of Abortion Coefficient ($\propto^2$) Squared of the Grown NiO Films Against Photon Energy (Sample F_4).

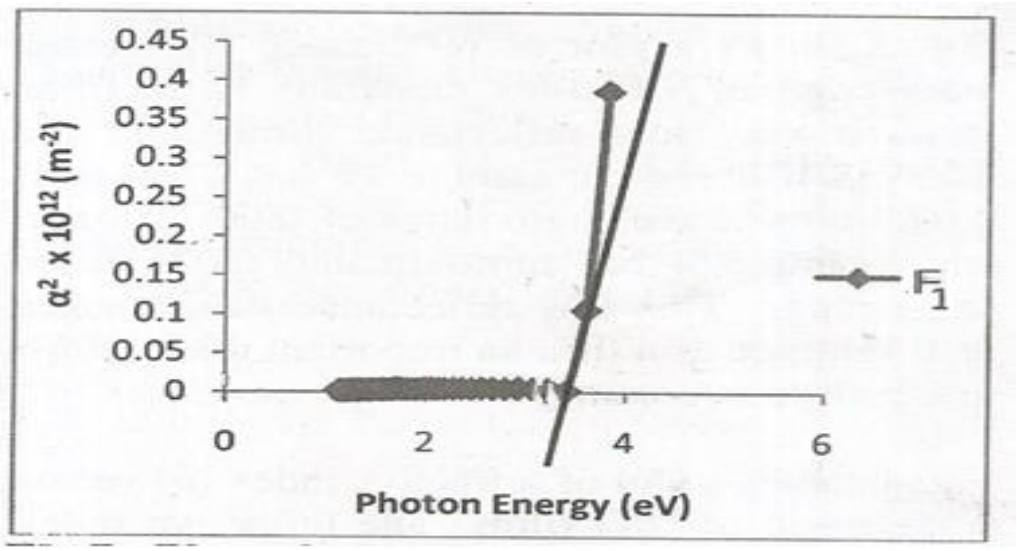

Fig. 7: Plot of Absorption Coefficient Squared $(\propto^2)$of the Grown NiO Films against Photo Energy (Sample F_1).

Fig. 6 and 7 above shows a plot of extinction coefficient squared against photon energy (hv) of NiO thin films. The energy for these films were obtained by extrapolating the linear part of the curves to the energy axis. It is observed from both figures that NiO thin film exhibits direct band transition and bandgap of 3.5eV and 3.8eV is obtained for sample F_1 and sample F_4 respectively. This energy bandgap values are in close agreement with the findings of Ezema et al (2007), who reported a bandgap of 3.6eV – 4.0eV.

Conclusion

The NiO thin film deposition technique under optimized deposition films have been prepared by the chemical bath deposition technique under optimized deposition conditions. Deposition was carried out from aqueous solutions using nickel chloride hexahydrate ($NiCl_2.6H_2O$) which served as the source on nickel ion, Ni^{2+}.The films exhibited low absorbance throughout the spectrum. The films also exhibited uniform transmittance of approximately 80% throughout the VIS/NIR region of the spectrum.

NiO revealed a refractive index of approximately 1.5 and 1.3 in the wavelength range of700 –11000nm for samples $F_1$and F_2 respectively.

Finally, the grown NiO thin film exhibited direct band transition and bandgap of 3.5eV and 3.8 eV for samples $F_1$and F_4 respectively.

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