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Study of the Optical Properties of Magnesium Oxide Thin Films Using the Electro-Deposition Technique.

Morka, J.C. [1], Nwachuku, D.N.[2], & Okoye, O.V.[3].
1,2 Physics Department, University of Delta, Agbor. Delta State, Nigeria.
3. Physics and Astronomy Department, University of Nigeria, Nsukka.

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Abstract

Using $MgSo_4.7H_2O$ as a starting precursor Magnesium oxide (MgO) thin films were effectively synthesised on Fluorine-doped Tin Oxide (FTO) glass substrates by electrode position method. By varying the deposition time, different thin films of thickness were prepared. An Ava-Spec-Uls 2048CL-2EV0 Spectrophotometer was used to obtain the absorbance spectra data. Other optical properties investigated from the calculation based on the data were, transmittance; Reflectance refractive index,thickness and band gap. Results obtained showed that MgO film thickness approximating 0.073µm to 0.125 µm for films deposited within the time range of 0.5minutes to 2.5minutes respectively. The highest value of 0.21 abr unit was observed in the UV region for the absorbance. Transmittance value of about 61% and 94% were observed in the UV and NIR regions of the EMSrespectively. Very high absorption coefficients (very low reflectance) were observed all through the UV-VIS NIR regions of the EMS. The thin films also recorded optical band gap, which ranged between 4.10 eV and 4.40 eV. The high transmittance value in the UV and NIR regions and the low reflectance of the MgO thin films make them suitable for optical applications and minimal light reflection respectively

***Corresponding Author:** Morka, J.C. john.morka@unidel.edu.ng

Introduction

Magnesium oxide is a naturally occurring compound of Magnesium and oxygen. Its chemical formula is MgO and consists of a lattice of Mg2+ ions and O^{2-} ions held together by ionic bonding. Magnesium oxide (MgO) is a moderately high dielectric constant material (Nisatharaju *et al.*,2014) with a very high band gap energy range of 4.50-5.25eV (Moses *et al.*,2007). Magnesium oxide due to its unique properties is used in many applications such as ultraviolet (UV) photodetectors (Liao *et al.*,2015), resistive switching (Samuel. *et al.,* 2023) and electrodes in pharmaceuticals and human fluids (Sultan *et al*.,2016).

MgO doping has been shown to effectively inhibit grain growth in ceramics and improve their fracture toughness by transforming the mechanism of crack growth between 1-100 nanometers (nm) (Tan *et al.*,2013).

In the past, several methods have been used to prepare MgO thin films and these are metal-organic decomposition (MOD) used to prepare Co ferrite thin films on MgO substrates (Minami *et al*,2015), Chemical Spray Pyrolysis technique used to deposit MgO nanostructured thin films with different thickness (Maher *et al* 2021) and Spin – Coating technique used to fabricate MgO pure and doped with Cerium thin films on Az31 alloy substrate (Ayse *et al*.2015). This study represents the successful growth of MgO layers on FTO substrates via electrochemical deposition. The wavelength range covered in the analysis of the absorbance spectra was 300nm - 1100nm.

Materials and Methods

Electrodeposition involves the deposition of materials onto substrates from a solution containing charged particles, driven by an electric potential. In this study, FTO substrates were coated with MgO thin films using electrodeposition techniques by dissolving 12.5g of $MgSO_4.7H_2O$ in 100ml of distilled water 0.5 M of magnesium sulphate ($MgSO_4.7H_2O$) was prepared and this provided the needed Mg^{2+}ion for the synthesis of MgO thin films by dissolving 0.25g of critic acid (Hexane-1,2,3-tricarboxylic acid) in 100ml of distilled water by dissolving 5.00g of NaOH in 100ml of distilled water, 1M of sodium hydrate (NaOH)was prepared. This substance acted as both a chelating agent and a PH buffer. The dip solution's chemical components are summarized in Table 1 below. Before the deposition of magnesium oxide on the Fluorine-doped Tin Oxide (FTO)substrate, the FTO substrates

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were made to undergo solvent clearing, using acetone
for about20 minutes to dissolve and remove grease,
ultra-sonicated for about 15 minutes an ultrasonic bath and finally dried in a temperature-controlled drying oven.

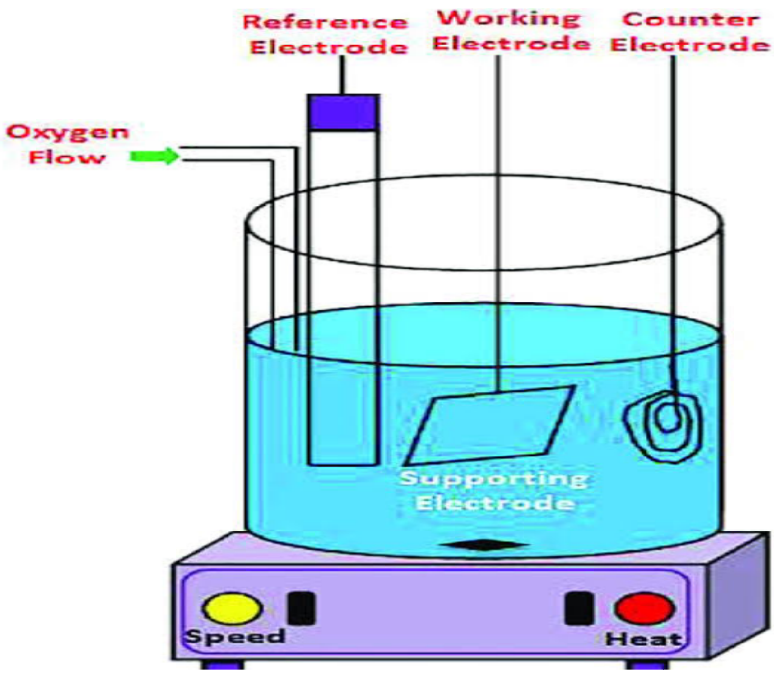

Figure 1: Diagram of the electrochemical deposition apparatus used in the experiment.

The components in the diagram are made up of the electrolytic cell (beaker), working electrode, anode(the electrode where oxidation occurs, platinum is used in this study), counter electrode(the electrode where reduction occurs), the power source DHRUVORO D'AZHENG PS-305D MODEL that drove the electrodeposition process, the saturated calomel electrode (SCE) used as the reference electrode, two digital multi-meters DT9Z01ACE model and thermometer (that was used to monitor the temperature of electrolyte solution which is essential for controlling the electrodeposition process).

The absorbance spectra of the deposited films were subsequently recorded from Ava-Spec-ULS 2048CL-2EVO spectrophotometer in a wavelength range of 300nm-1100nm.Other optional properties such as transmittance reflectance refractive, index, optional thickness and band gap were calculated from known empirical relationships shown below as demonstrated by(Jania *et al*,1979, Ozuomba and Ekpunobi, 2024, Kariper*et al*, 2018).

(a) Transmittance (T), $T = 10^{-A}$, where A=absorbance

(b) Reflectance (R), R= 1-(A+T)

(C) Refractive index (Π) $= \frac{1+ R^{1/2}}{1-R^{1/2}}$

(d) Optical part length (Thickness (t)), $t = [\frac{1-R^2/T}{\propto}]$

Where $\propto$ = Coefficient of absorption;

$\propto = \frac{Å}{\lambda}$

Where λ= wavelength

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Table 1: Chemical composition for maximizing and minimizing of MgO deposition time.

Bath Name	Chemicals	Concentration (mol)	Volume (ml)	pH	Time of Deposition (mins)	Current I (mA)	Temperature (K)
MgO : A	$MgSO_4.7H_2O$ Citric acid NaOH	0.5 0.5 1.0	10.00 10.00 15.00	8.8	0.5	2.69	305
MgO : B	$MgSO_4.7H_2O$ Citric acid NaOH	0.5 0.5 1.0	10.00 10.00 15.00	8.8	1.0	2.52	305
MgO: C	$MgSO_4.7H_2O$ Citric acid NaOH	0.5 0.5 1.0	10.00 10.00 15.00	8.8	1.5	2.56	305
MgO: D	$MgSO_4.7H_2O$ Citric acid NaOH	0.5 0.5 1.0	10.00 10.00 15.00	8.8	2.0	2.39	305
MgO: E	$MgSO_4.7H_2O$ Citric acid NaOH	0.5 0.5 1.0	10.00 10.00 15.00	8.8	2.5	1.53	305

Results and Discussion

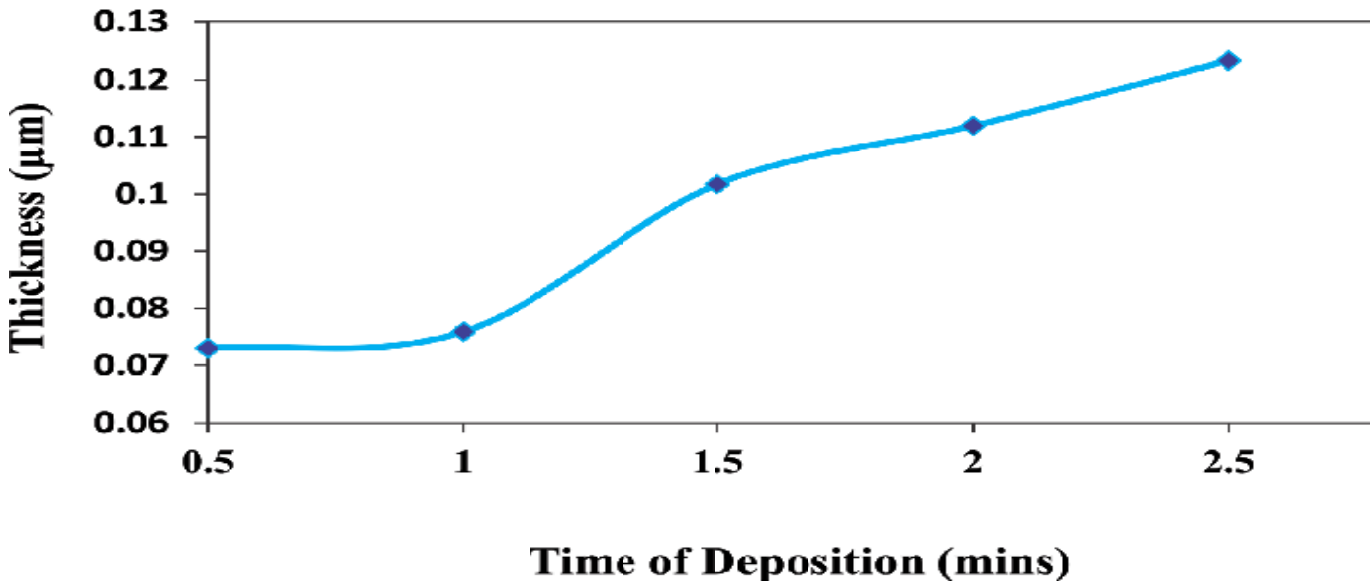

Figure 2: Graph of film thickness (µm)against time of deposition (mins) for MgO Thin film

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Figure 2 showed that the film thickness specifically, for films deposited at 0.5 minutes and 2.5 minutes, the thickness increased from about 0.073 µm to about 0.125 µm respectively.

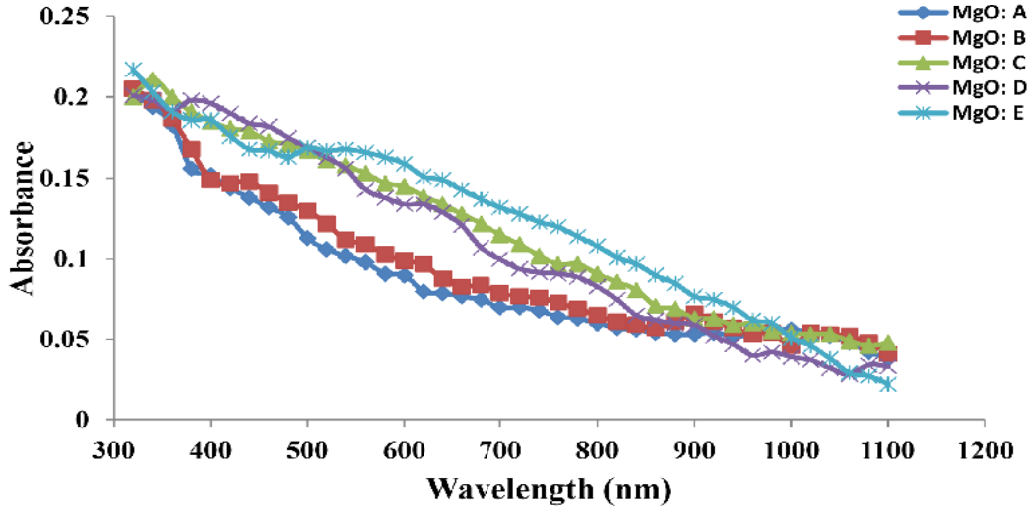

Figure 3:Graph of absorbance against wavelength for MgO Thin film

Figure 3 had the highest absorbance value of 0.21 abr unit in the UV region of the EMS. Generally, absorbance decreased with an increase in wavelength, with very low values in the UV-Vis-NIR spectrum space.

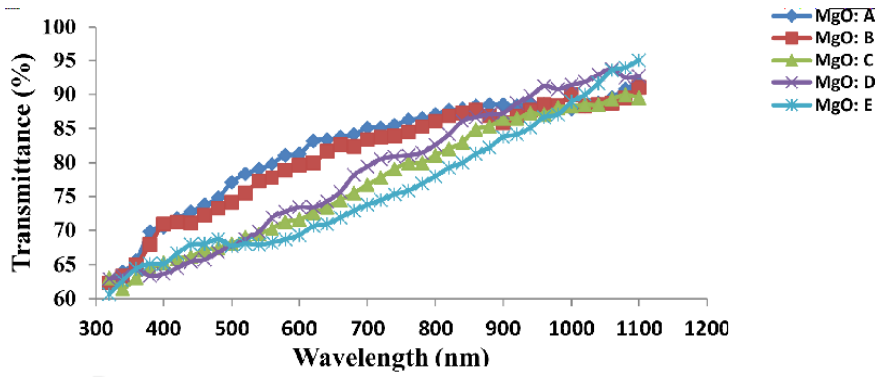

Figure 4: Graph of transmittance against wavelength for MgO Thin film

Figure 4 shows that transmittance increased with an increase in wavelength..The transmittance was high all through the spectrum range having about 60 % in the UV region and about 94 % in the NIR region.

The high transmittance of the deposited film position is for solar energy collection, because of coated on the surface of a collector, it will reduce the reflection of solar radiation and transmit radiation to the collector fluid (Egwunyenga *et al.*,2021)

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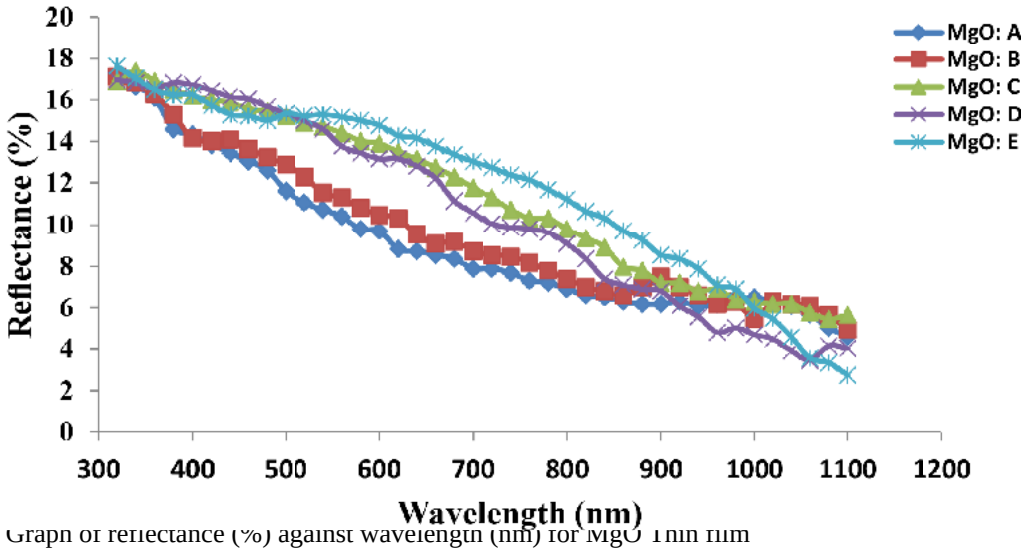

Figure 5: Graph of reflectance (%) against wavelength (nm) for MgO Thin film

Figure 5, shows that all the films had very low reflectance throughout the UV- VIS-NIR regions of the EMS with the highest value of 18%in the UV regions

This low reflectance value makes the MgO thin films suitable materials for anti-reflection coating. The films can also prevent excessive solar glare (Haruna *et al.*, 2015).

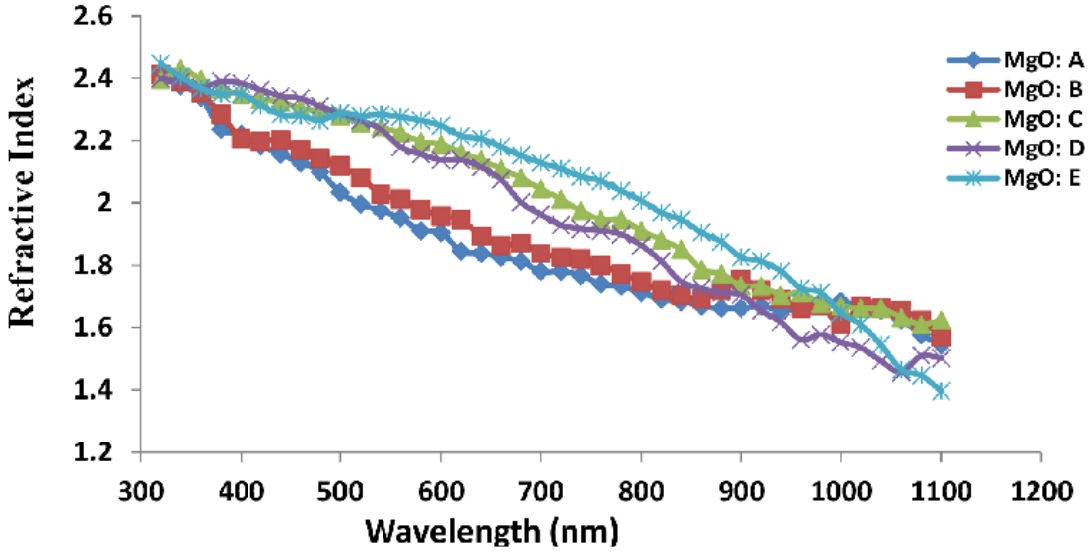

Figure 6: Graph of the refractive index against wavelength (nm) for MgO Thin film

Figure 6 showed that the refractive index of the MgO thin films decreased as the wavelength increased, with values of about 2.45 and 1.4 in the UV-VIS regions of the EMS, respectively.This high refractive index

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makes the Mg0 thins films suitable for use in glass reflective coating as applied during the float process to enhance the amount of heat reflected by the glass (Ekwealor *et al*:.,015)

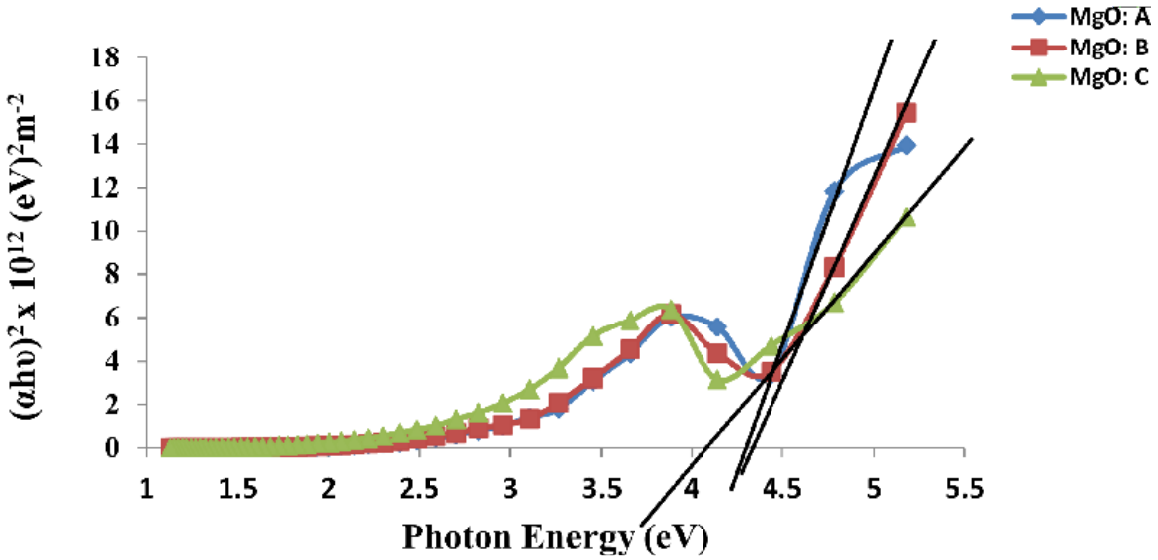

Figure 7: Graph of absorption coefficient squared against photon energy

Figure 7 shows the plot of the absorption coefficient squared $(\propto h\nu)^2$ against photon energy for MgO thin films for bath MgO: A MgO: B and MgO: C respectively.The optical energy band gap was determined by extrapolating the straight-line part of the plot to the photon energy axis. The values of the band gap energy for MgO films deposited at A, B and C were 4.10 eV, 4.30 eV an 4.40 eVrespectively.
Thus figure 7 revealed wide band gap energy values which ranged from 4.10 eV to 4.40 eV. These values of band gap energy are in line with values obtained by (Kokkonen *et al*; 2021).
The wide band gap recorded inthis study positions the thin films as for coating of absorber layers of solar panels (Bart *et al.,* 2019).

Conclusion

In this study, MgO thin films were prepared using the electro-deposition technique under refined deposition conditions for optimal results. This study revealed that the electro-deposited magnesium oxide thin films exhibited exceptional optical properties, including a high refractive index ranging from 1.4 to 2.45 in the UV and NIR regions of the EMS respectively; and a wide optical band gap which ranged from 4.10 eV to 4.40 eV making them suitable for applications in ultraviolet photodetectors and optical sensors.
These findings demonstrate the potential of magnesium oxide thin films as a cost-effective and scalable material for advanced optical applications.

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