EFFECT OF THICKNESS ON THE OPTICAL PROPERTIES OF MAGNESIUM OXIDE THIN FILMS GROWN BY SOLUTION GROWTH TECHNIQUE

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ABSTRACT

Magnesium oxide thinfilms were grown on glass substrates using solution growth method at room temperature 300K. The films were synthesized using 0.2M $Mg(NO_3)_2.6H_2O$ as source of cation and 0.2M NaOH as source of anion. Effect of thickness on the optical properties of the films were investigated at wavelengths of 200nm to 1100nm. Results of the work show that optical properties are directly proportional to the thickness of the films except the transmittance which exhibits inverse relationship. However the transmittance is high in the UV-VIS-NIR region while absorbance and reflectance are low.

***Key words**: Thin films, optical properties, absorbance, transmittance*

1. INTRODUCTION

MgO is a highly ionic solid with an electronegativity difference of 2.13. Moreover, its cation/anion radius ratio of 0.50 implies that it is stable only in the common rock salt (NaC1) crystal structure [1]. MgO thinfilms have been widely used as a chemically stable buffer layer for the deposition of high Tc superconducting films and perovskite-type ferroelectric films because of its good lattice matching with mentioned materials and low chemical reactivity [2]. Magnesium oxide is one of several materials used as thin insulating layers in electronic devices [3]. It has the advantage of remaining chemically stable at the elevated temperatures at which subsequent thin layers may be grown. Magnesium oxide is technologically important material that has been studied as a high k-dielectric[4], a barrier for Josephson tunnel junctions[5], a substrate for the heteroepitaxialovergrowth of high T_c super conductor films[6], a protective coating on the walls of plasma devices[7], and in many other applications.the utility of MgO stems fromits wide bandgap of 7.eV, high melting point of 2800^0C and a stable large yield of secondary electrons when its surface is bombarded with ion[8]

2. MATERIALS AND METHOD

Magnesium oxide thin films for this experiment were synthesized by simple, cheap and cost effective solution growth technique, otherwise called chemical bath deposition method. Five empty microscope slides serving as the substrates were degreased by soaking in concentrated trioxonitrate (V) acid for 15 minutes then washed with detergent. They were rinsed with distilled water and allowed to dry in a clean environment. Five 50ml beakers were also washed with detergent and rinsed with distilled water. These served as the reaction bath container.

The precursors were: 0.2m solution hexahydrated magnesium trioxonitrate (V) as source of magnesium ion and 0.2 molar solution sodium hydroxide (NaOH) as source of OH^- ions. The deposition time, volume and concentration of $(Mg(No_3)_{2.}6H_2O)$,were kept constant while the volume of NaoH was varied from 10ml to 50ml in intervals of 10ml as shown in table 1. The deposited films were annealed at temperature of 200^0C for 5mins. The deposited MgO thin films were characterized and analyzed for their optical properties viz; absorbance and transmittance using UV/Visible spectrophotometer throughout the UV, Visible and Near infrared region of the electromagnetic spectrum, while other optical properties like refractive index, reflectance and extinction coefficient were calculated using appropriate formulae.

The reaction mechanism upon hydrolysis is of the form:

$Mg(NO_3)_2.6H_2O) \rightleftharpoons Mg^{++} + 2NO_3^- + 6H_2O$

$NaOH \longrightarrow Na^+ + OH^-.$

Then Mg^{++} and OH^- combine to form $Mg(OH)_2$ as follows

$Mg^{++} + OH^- \longrightarrow Mg(OH)_2.$

Upon annealing

$$Mg(OH)_2 \xrightarrow{\Delta\ 200^{\bullet C}} MgO.$$

Table 1: Deposition of MgO thin film

Reaction bath	Deposition time t(hr.)	$Mg(NO_3)_2.6H_2O$		NaOH	
		Conc (M)	Vol (ml)	Conc (M)	Vol (ml)
B_1	4	0.2	25	0.2	10
B_2	4	0.2	25	0.2	20
B_3	4	0.2	25	0.2	30
B4	4	0.2	25	0.2	40
B_5	4	0.2	25	0.2	50

3. THEORY

3.1: Reflectance: R= 1-(A+T)
A is absorbance, T is transmittance

3.2: Extinction coefficient: $k = \frac{\alpha\lambda}{4\pi}$
$\alpha\ is\ absorption\ coefficient$, λ is wavelength

3.3: Refractive index: $n = \frac{1+\sqrt{R}}{1-\sqrt{R}}$
R is reflectance

3.4: Dielectric constant (real part): $\varepsilon_r = n^2 - k^2$
N is refractive index, k is extinction coefficient,

3.5: Dielectric constant (imaginary part): $\varepsilon_i = 2nk$

3.6: Thickness: $t = \frac{Ln\left[\frac{(1-R)^2}{T}\right]}{\alpha}$
R is reflectance, T is transmittance, $\alpha\ is\ Absorption\ coefficient$

4. RESULTS

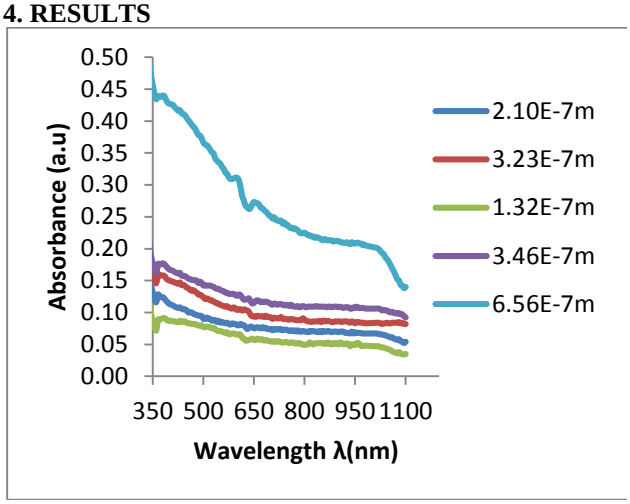

Fig. 1: Variation of absorbance with wavelength

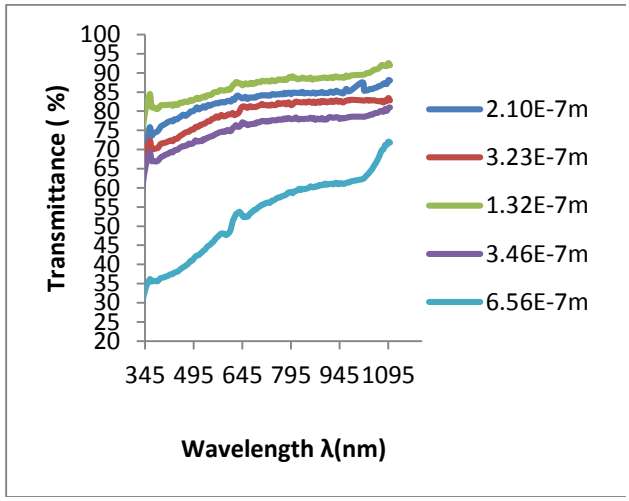

Fig. 2: Variation of percentage transmittance with wavelength

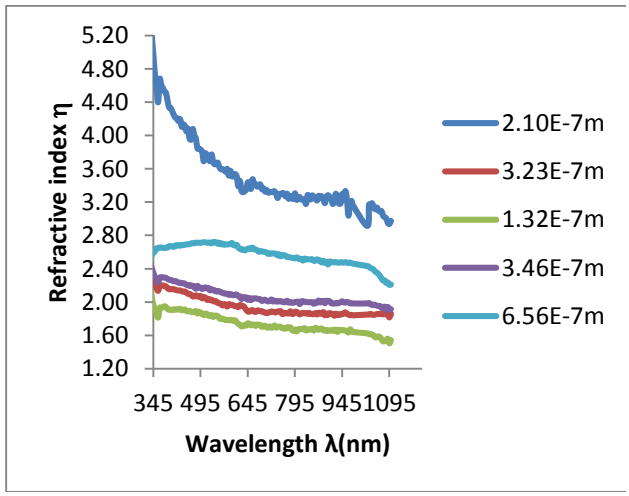

Fig.4: Variation of refractive index with wavelength

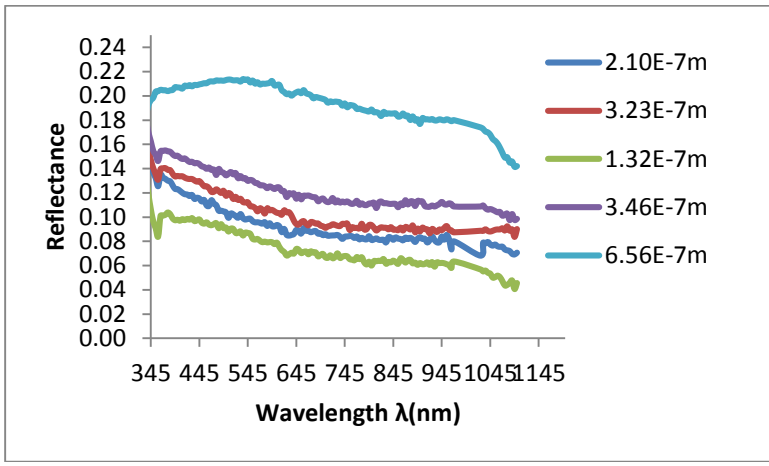

Fig. 3: Variation of reflectance with wavelength

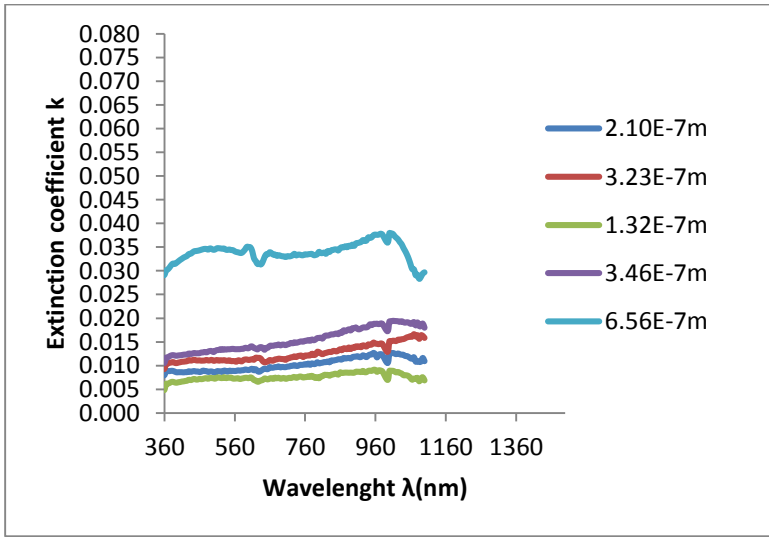

Fig.5: Variation of extinction coefficient with wavelength

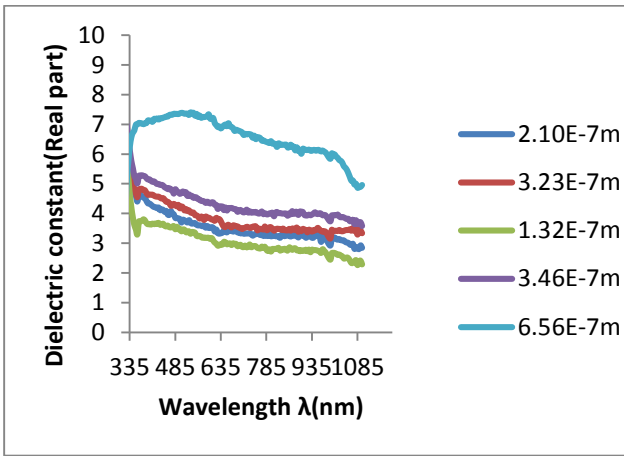

Fig. 6: Variation of dielectric constant(real part) with wavelength

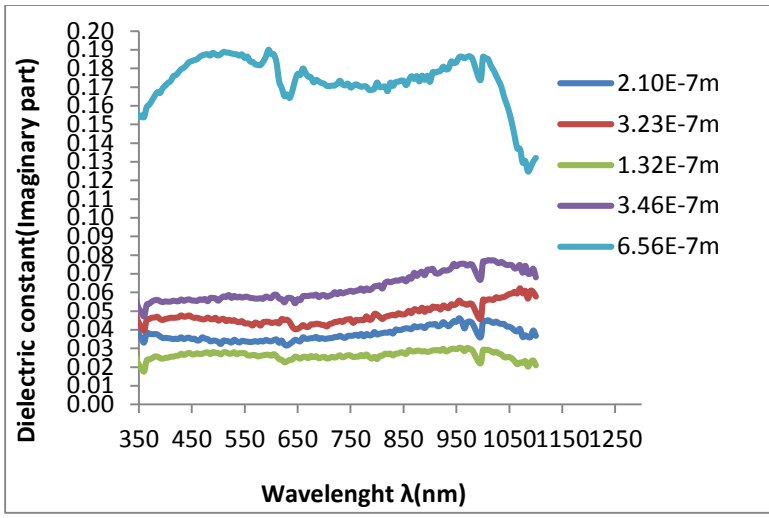

Fig.7: Variation of dielectric constant(imaginary part) with wavelength

5. DISCUSSIONS

As shown in fig. 1, absorbance of the films is generally low in all the regions of electromagnetic spectrum, maximum of 0.438=43.8% in UV region for the thickest film (6.56E-7m). The absorbance is directly proportional to the thickness of the films. Fig.2, shows that the films have high transmittance in all the regions, minimum of 66.97% in UV region for second thickest film(3.46E-7m) and maximum of 92.54% in the NIR region for the thinnest film(1.32E-7m). However, transmittance of the thickest film(6.56E-7m) is exceptionally fairly low in the UV region- 35.6% and increases to maximum in the NIR-71.8%. Results as shown in fig.3, show that the films have low reflectance in all the regions, maximum of 0.2133= 21.33% in the visible region for the thickest film(6.56E-7m). Reflectance of the films is directly proportional to the thickness of the films. This property of low absorbance, low reflectance and high transmittance makes it a good material for solar cell and photothermal applications. It is also a good material for coating of windows of poultry house since high doses of IR can be transmitted into the room to warm up the chicks. Low reflectance makes it a veritable material for anti reflection coating .The films have high refractive index in all the regions as shown in fig.4. The thickest film (6.56E-7m) has refractive index of 4.67 in UV region and decreases to 3.18 in NIR region whereas the thinnest film(1.32E-7m) has refractive index of 1.82 in UV region and decreases to 1.57 in NIR region. This makes it a good material for antireflection film pack. The refractive index is directly proportional to the thickness of the films. As shown in figs. 5, 6 and 7, the extinction coefficient, dielectric constants (real and imaginary) are directly proportional to the thickness of the films.

6. CONCLUSION

Magnesium oxide thin film can be prepared by solution growth technique.

The films have low absorbance, reflectance in the UV-VIS-NIR regions but high transmittance in the whole regions. The optical properties viz; absorbance, reflectance, refractive index, dielectric constants are directly proportional to the thickness of the film while transmittance is inversely proportional.

7. REFERENCES

1. M. G. Kim, U. Dahmen, W. S. Allan, (1987): tructural Transformations in the Decomposition of Mg $(OH)_2$ and MgCO, *Journal of American Ceramic Society*, **70**,146,(1987).

2. M. Gurvitch, A. T. Fiory, Preparation and Substrate Reactions of Superconducting Y-Ba-Cu-O Films *Appllied Physics Letters*, **51,** 1027,(1978)

3. D. K. Fork, F. A. Pounce, J. C. Tramontana, *Jpn. J. Appl. Phys.* 32, 4099,(1993).

4. J. Kim, B. Gila, R. Mechandru, J.W. Johnson, J.H. Shin, K.P. Lee, B. Luo, A. Onstine, C.R. Abernathy, S.J. Pearton, and F. Ren, Electrical characterization of GaN metal oxide semiconductor diodes using MgO as the gate oxide, J. Electrochem. Soc. **149**(8), G482,(2002).

5. A. Kawakami, Y. Uzawa and Z. Wang, Development of epitaxial NbN/MgO/NbN-superconductor-insulator-

superconductor mixers for operations over the Nb gap frequency, Appl. Phys. Lett. **83**(19),3954, (2003)

6. P. N Arendt and S. R Foltyn, Biaxially textured IBAD-MgO templates for YBCO-coated conductors, MRS Bull. **29**(8), 543,(2004)

7. H. S Jung, J. K. Lee, K.S. Hong and H. J. Youn, Ion induced secondary electron emission behaviour of sol-gel derived MgO thin films used for protective layers in alternating current plasma display panels, J. Appl. Phys, **92**(5),2855,(2002).

8. W. B. Wang, Y. Yang, A. Yanguas-Gil, N. N. Chang, G. S Girolami, J. R. Abelson, Highly conformal magnesium oxide thin films by low temperature chemical vapour deposition from $Mg(H_3BNMe_2BH_3))_2$ and water, Applied physics letters, **102**, 101605, (2013)