# OPTICAL PROPERTIES OF ALUMINIUM OXIDE THIN FILM GROWN BY SOLUTION GROWTH TECHNIQUE

**AHANAONU, N[1]., EZENWAKA, LAZ[1], UMEOKWONNA, N. S[1*].**
Department of Industrial Physics, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.

*ABSTRACT*
*Thinfilms of Aluminium oxide were grown by solution growth technique using aluminum chloride solution and ammonia solution as precursors. Optical properties of the films were characterized using spectrophotometer in UV-VIS-NIR regions of electromagnetic spectrum. Results of the work showed that the films had low absorbance and reflectance in all the regions while transmittance and refractive index were high in UV-VIS-NIR regions. The film had band gap which ranged from 1.9 to 3.5eV. X-ray analysis showed that the film had cubic crystal structure.*

**Key words**: **Thin film. Semiconductor, optical properties, band gap**

## 1. INTRODUCTION

Aluminum oxide, ($Al_2O_3$) commonly is known as alumina (Gitzen, 1970). The oxide is also one of the reasons for the appealing properties of the metal aluminum – a stable, thin, aluminum oxide scale forms naturally on metallic aluminum in air, thereby protecting the metal from further oxidation and consequently being the reason for the good corrosion resistance of aluminum (Van Horn, 1967**)**. Alumina in bulk form is one of the most widely used ceramics (Gitzen, 1970). In the crystalline phase known as α-alumina, it is commonly referred to as corundum. The development of aluminum oxide as a thin film material has been pushed forward by applications such as; wear protective coatings in the cutting tool industry (Funk*et al.*, 1976, Ruppi, 2005), as an insulating layer in semiconductor devices (Specht*et al.*, 2005; Ye and Yang, 2005) and as tunnel barrier in special thin film structures (Oh *et al*., 2005; Bataileet *al.*, 2005). In industry, protective alumina coatings on cemented carbide cutting tools, deposited using chemical vapor deposition techniques, have been used for several decades (Funk*et al.*, 1976). These are still widely utilized and developed, due to the beneficial mechanical, chemical, and thermal properties of alumina (Ruppi, 2005).

## 2. MATERIALS AND METHOD

The substrates were prepared for use by soaking in nitric acid for 48 hours, washed with water and detergent, then rinsed with distilled water and hung in air to dry. The precursors used for the deposition of the films were Aluminum chloride ($AlCl_3$) serving as source of Aluminum ion, ammonium hydroxide($NH_4OH$) serving as both oxidizing agent and pH adjuster, distilled water. Five bath set ups were prepared, each containing 4ml of ammonium hydroxide, 3ml of aluminum chloride and 35ml of added water as shown in table 1. The pH of each set up is 9.7. The deposition was carried out at 301K. The slides were removed after 40 hrs, 42 hrs, 44 hrs, 46 hrs and 48 hrs respectively. They were rinsed with distilled water and hung in a clean environment to dry. After drying, they were annealed at 250K for 30 mins. UV-Spectrophotometer was used to characterize the films for absorbance while other optical properties viz; transmittance, reflectance, absorption coefficient, refractive index, extinction coefficient and band gap were calculated using the appropriate mathematical tool. XRD diffractometer was used to determine the structural property and Olympus microscope used for determination of film morphology.

Table 1: Time variation for deposition of $Al_2O_3$ thin film

| Slide No | $AlCl_3$conc. ($mol/dm^3$) | $AlCl_3$ Vol. (ml) | $NH_4OH$ Vol.(ml) | Distilled waterVol. (ml) | Time (hrs) | pH | Annealing temp. (Kelvin) | Annealing time (mins) |
|---|---|---|---|---|---|---|---|---|
| 6 | 0.3 | 3.0 | 4.0 | 35.0 | 40.0 | 9.7 | 250 | 30.0 |
| 7 | 0.3 | 3.0 | 4.0 | 35.0 | 42.0 | 9.7 | 250 | 30.0 |
| 8 | 0.3 | 3.0 | 4.0 | 35.0 | 44.0 | 9.7 | 250 | 30.0 |
| 9 | 0.3 | 3.0 | 4.0 | 35.0 | 46.0 | 9.7 | 250 | 30.0 |
| 10 | 0.3 | 3.0 | 4.0 | 35.0 | 48.0 | 9.7 | 250 | 30.0 |

## 3. THEORY

**Calculation of optical properties**

The following formulae were used to calculate the optical properties of the films.

**3.1: Reflectance**

The Reflectance

$R = 1 - (A + T)$ (1)

Rubby and Suman (2011) A is absorbance, T is transmittance.

**3.2: Refractive index (n)**

$n = \frac{1+\sqrt{R}}{1-\sqrt{R}}$ (2)

Rubby and Suman (2011) Ris reflectance

**3.3: Transmittance**

$T = 10^{-A}$ (3)

A is absorbance of the film

**3.4: Extinction coefficient (k)**

$k = \frac{\alpha\lambda}{4\pi}$ (4)

Nabeel (2011), α is absorption coefficient and λ is wavelength

**3.5: Absorption coefficient (α)**

$\alpha = \frac{A}{\lambda}$(5)

A is Absorbance and λ is wavelength

**3.6: Photon energy (hυ)**

E = hυ (6)

Nadeem *et al.,* (2000) h = Planck's constant = $6.63 \times 10^{-34}$Js, υ = frequency of photon,

However,$\nu = \frac{c}{\lambda}$ c = velocity of light = 3x$10^8$m/s and λ = wavelength,

Hence,$E = \frac{hc}{\lambda}$, but, $1eV = 1.602 \times 10^{-19}J$ , Planck's constant

$$h = \frac{6.63 \times 10^{-34}Js}{1.602 \times 10^{-19}J} \approx 4.14 \times 10^{-15}eV$$

∴ Photon energy $E = \frac{4.14\times10^{-15}eV\times3\times10^{8}m/s}{\lambda(m)}$eV

## 4. RESULTS

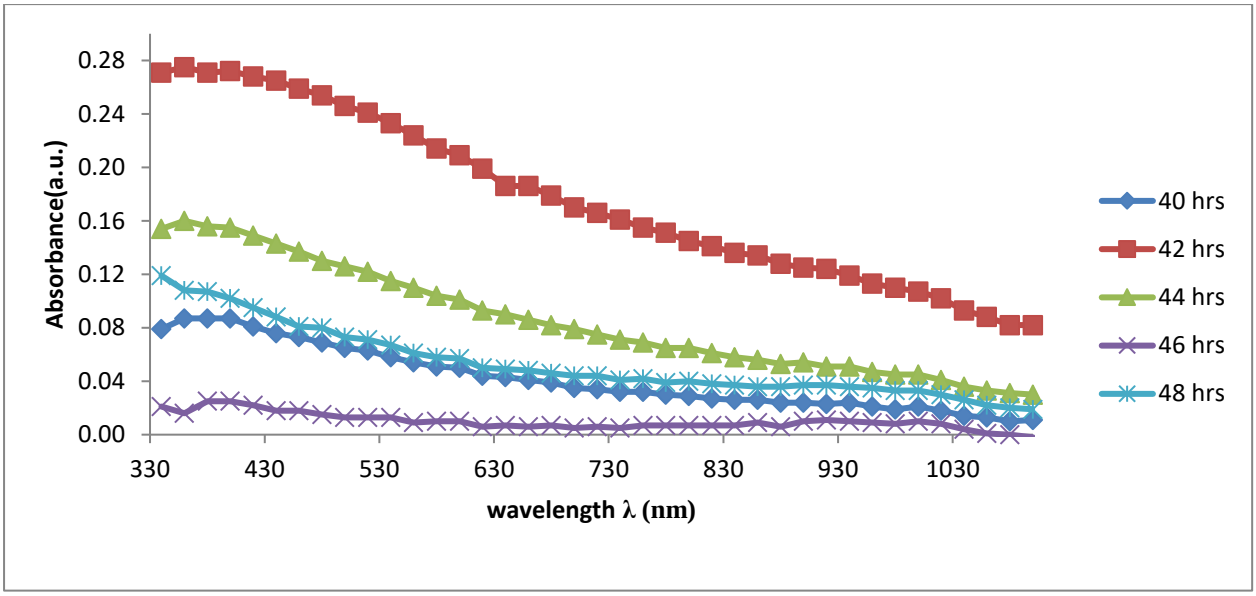


Fig. 1: Variation of absorbance with wavelength

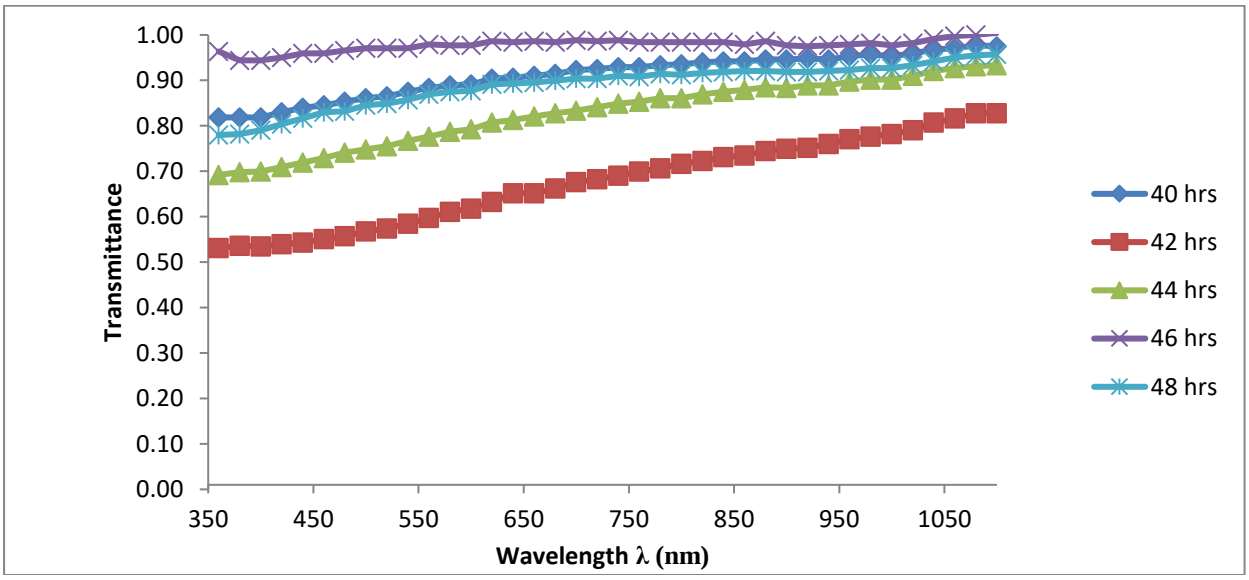


Fig. 2: Variation of transmittance with wavelength

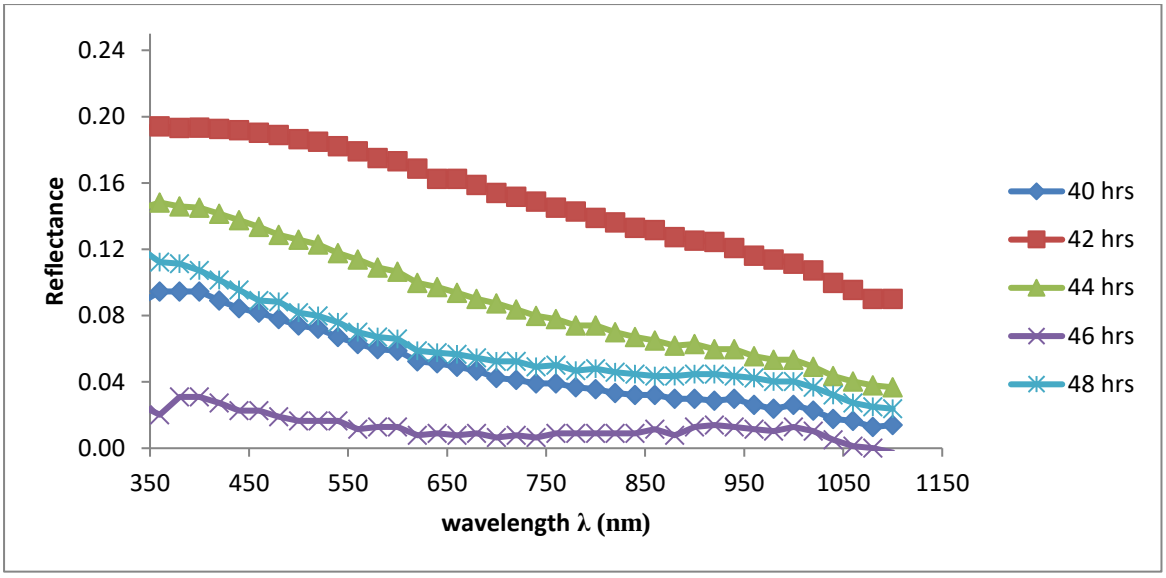


Fig. 3: Variation of reflectance with wavelength

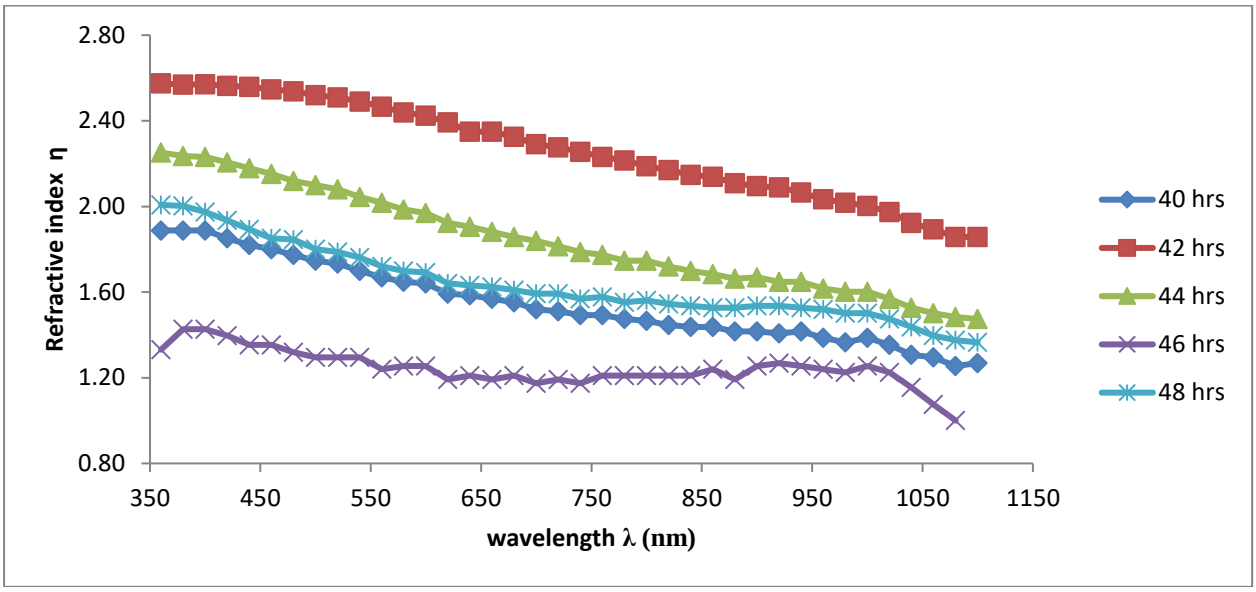


Fig. 4: Variation of refractive index with wavelength

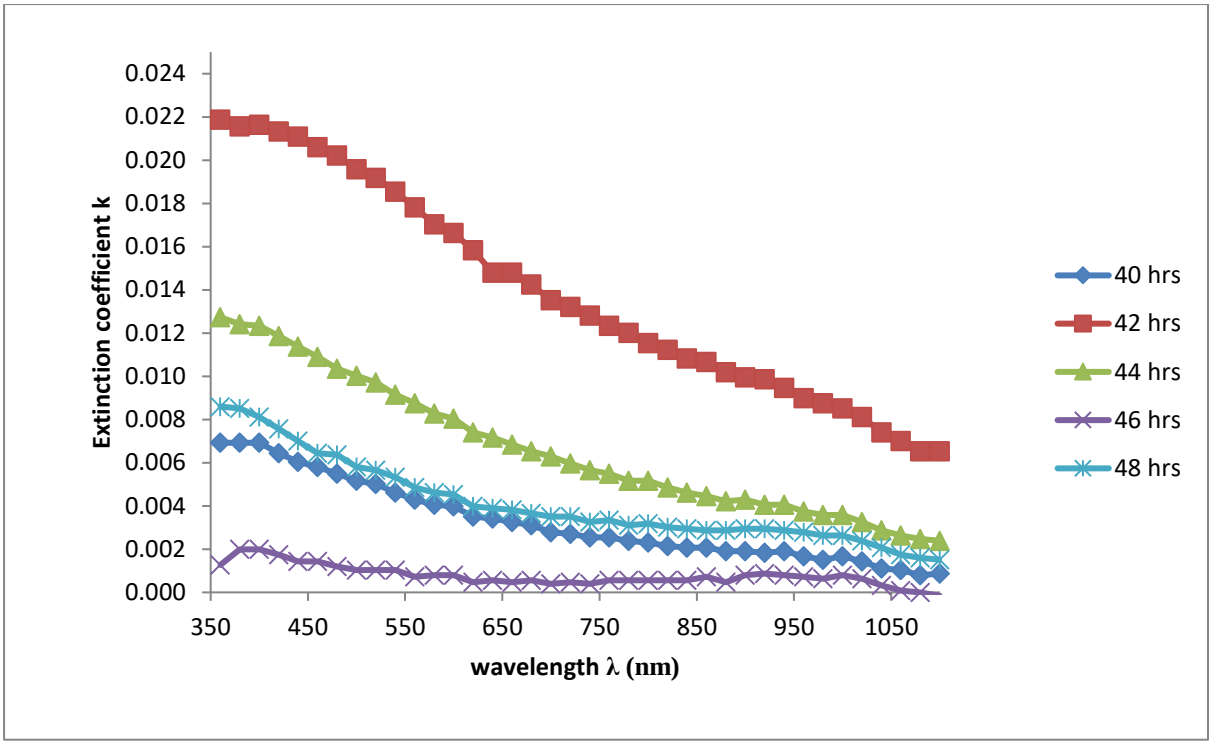


Fig. 5: Variation of extinction coefficient with wavelength

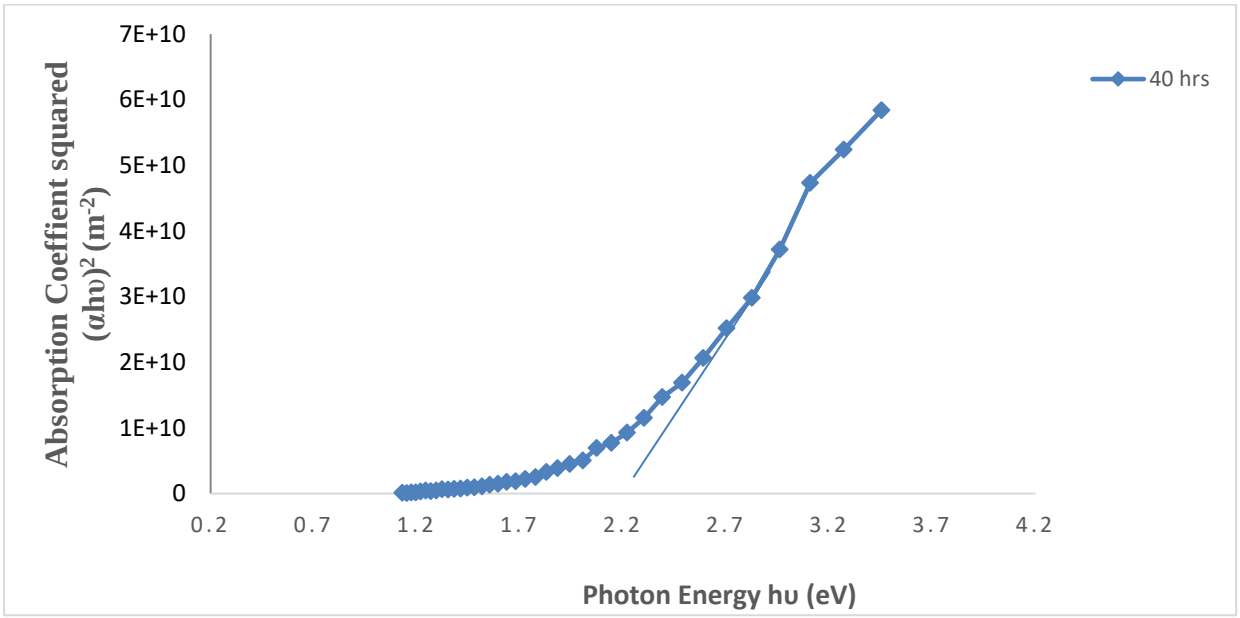


Fig. 6: Absorption coefficient squared versus photon energy for 40hrs deposition time

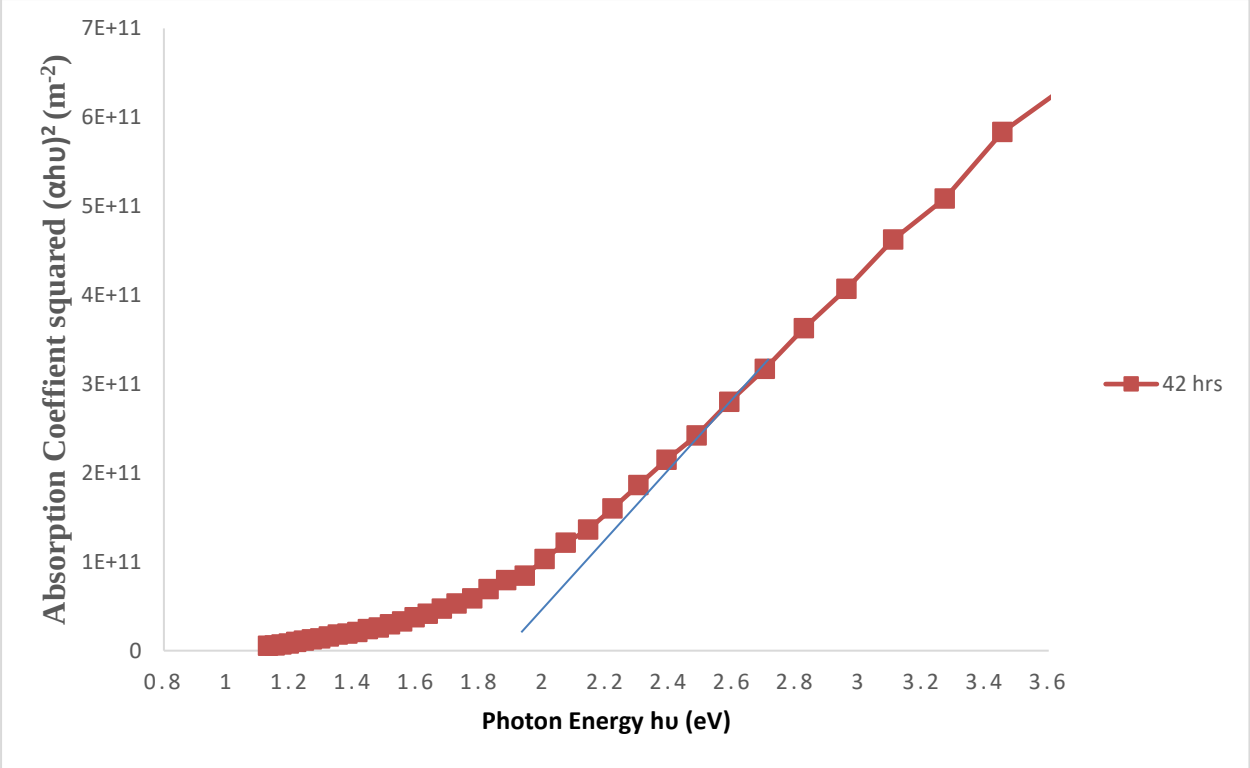


Fig. 7: Absorption coefficient squared versus photon energy for 42hrs deposition time

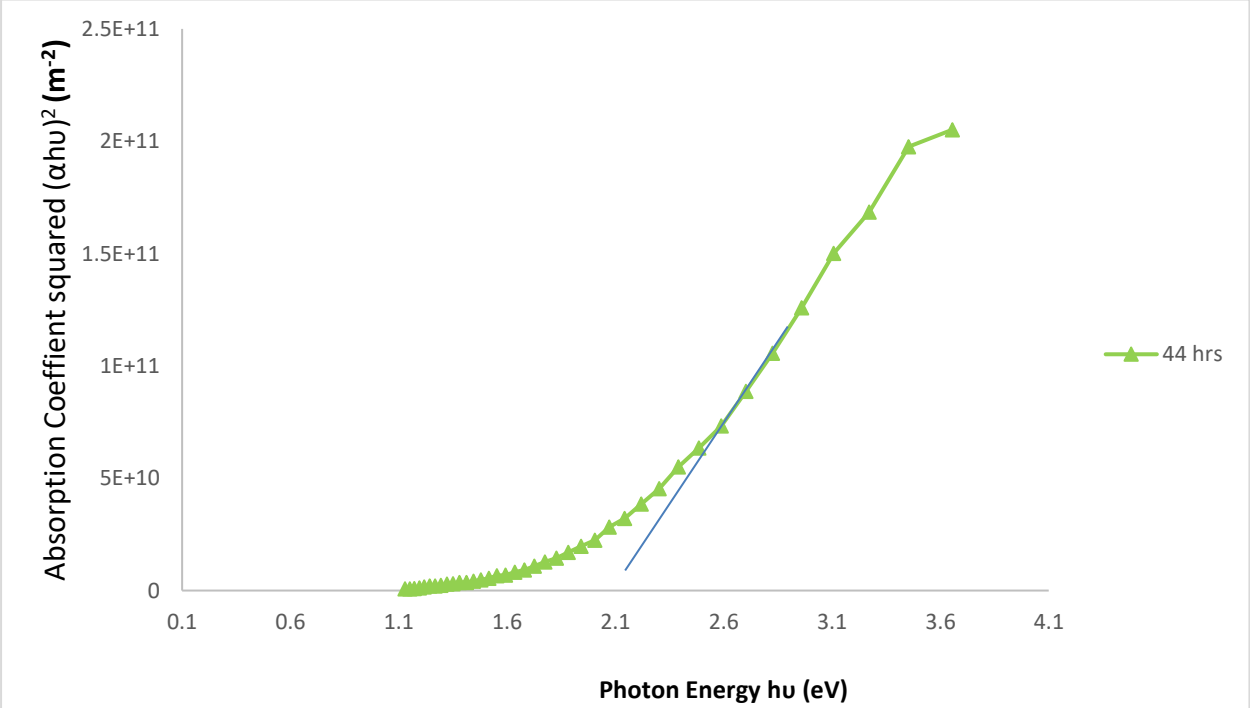


Fig. 8: Absorption coefficient squared versus photon energy for 44hrs deposition time

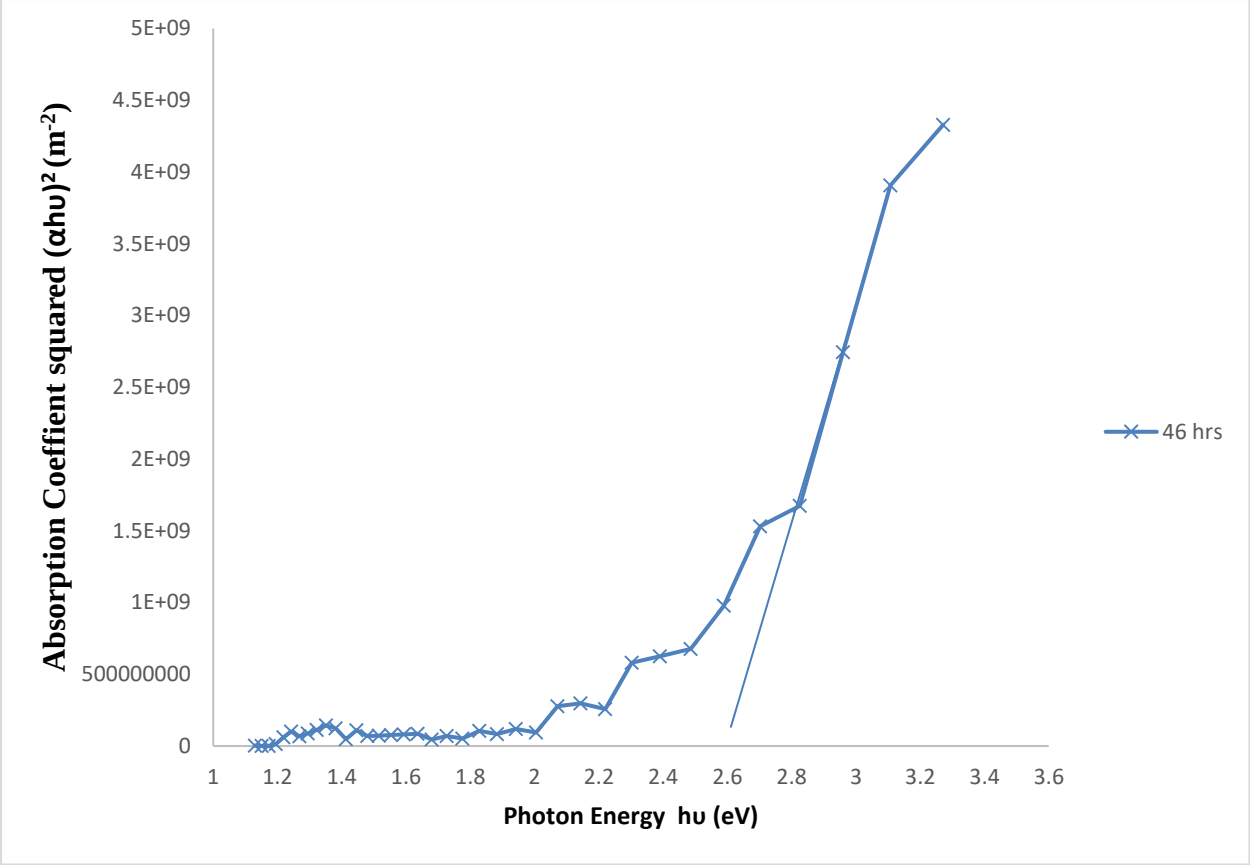


Fig. 9: Absorption coefficient squared versus photon energy for 46hrs deposition time

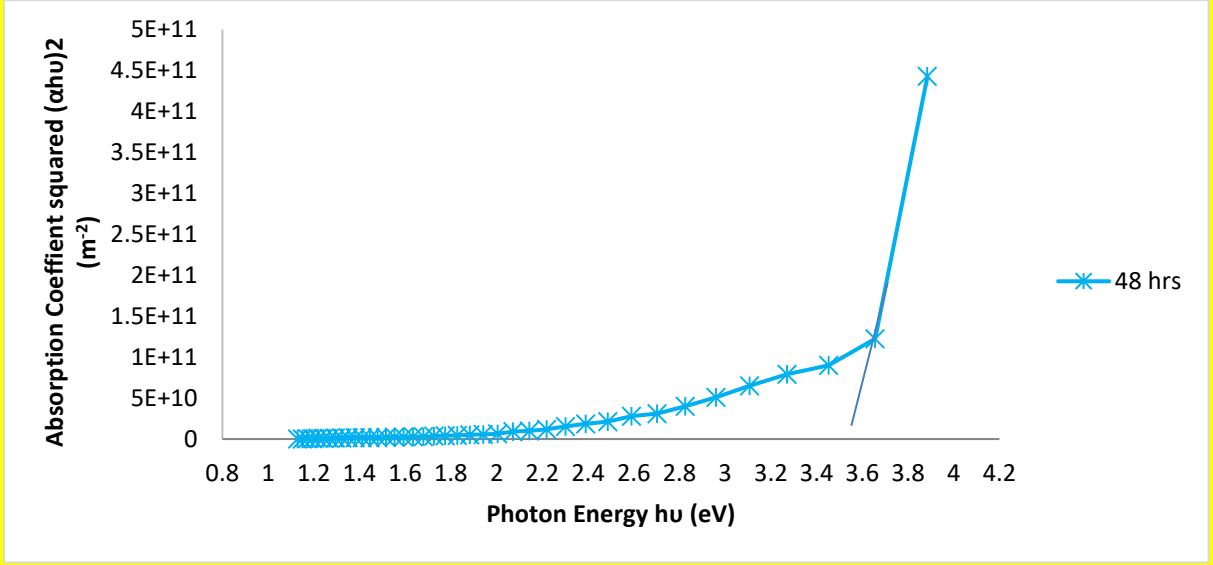


Fig. 10: Absorption coefficient squared versus photon energy for 48hrs deposition time

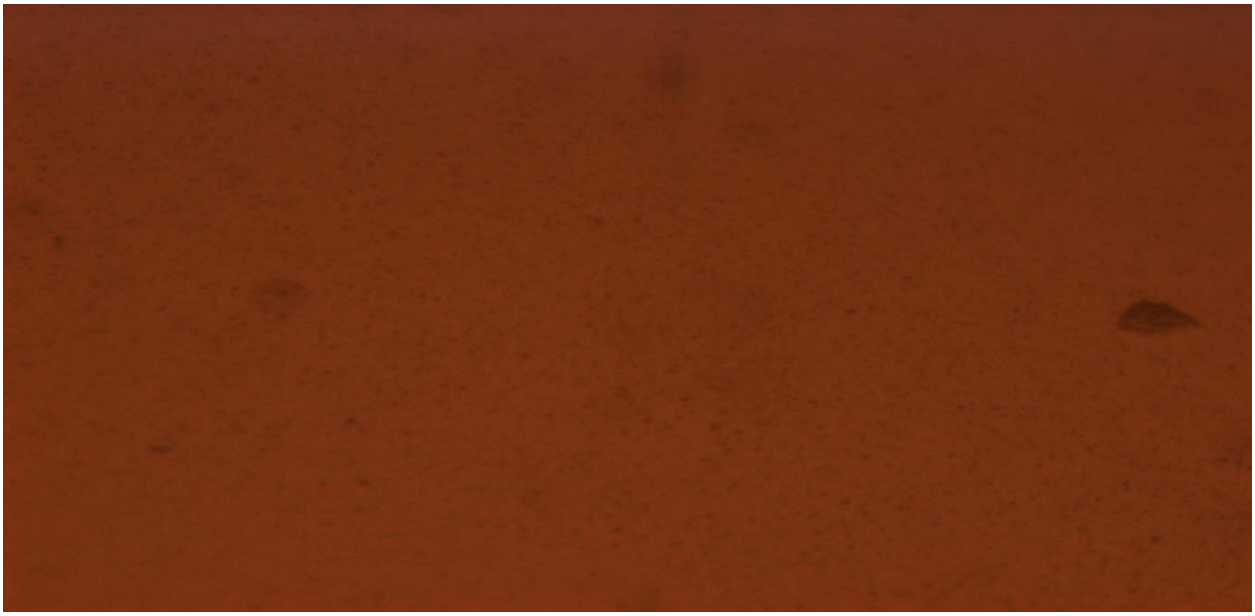

Fig. 11: Micrograph of $Al_2O_3$thin film

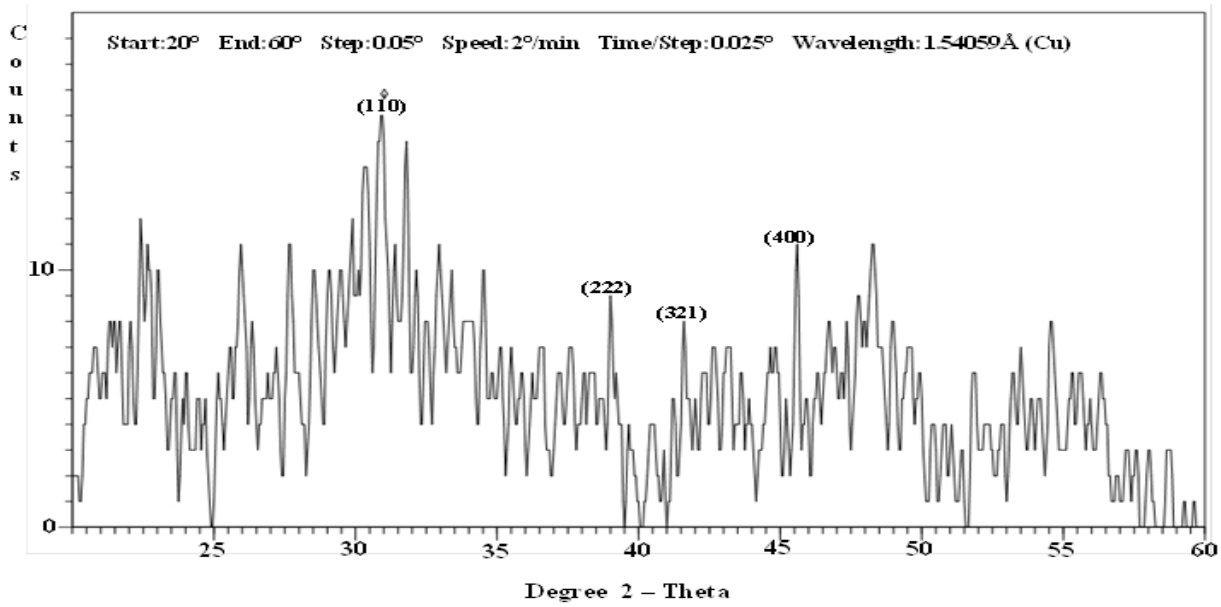


Fig. 12: XRD pattern of $Al_2O_3$ thin film

## 5. DISCUSSIONS

As shown in fig. 1, absorbance of the film is very low; maximum of 0.27=27% in UV region and decreases to minimum in NIR region. Absorbance of the film varies inversely with wavelength. From fig. 2, the film has high transmittance; 0.99 = 99% in NIR region and minimum of 0.53= 53% in UV region. It varies directly with wavelength. Fig. 3 shows that the film has very low reflectance; Maximum of 0.19 = 19% in UV region and decreases to minimum in NIR region. The reflectance varies inversely with wavelength. The low absorbance and reflectance and high transmittance makes the film a good material for solar cell and photo thermal heating. Refractive index of the film is high as shown in fig. 4. Maximum of 2.58 and minimum of 1.33 in UV region and decreases to minimum in NIR region. It varies inversely with wavelength. The high refractive index makes the film useful in film stack for antireflection coating. As shown in fig. 5, the film has maximum extinction (0.02) in UV region and decreases

to minimum in NIR region. The extinction coefficient varies inversely with the wavelength. Fig. 6-10 shows the band gap of the films. 2.2eV for 40hrs, 1.9eV for 42hrs, 2.1eV for 44hrs, 2.6eV for46eV and 3.5eV for 48hrs deposition time. The film has a wide band gap and as such is applicable in more efficient light emitting diodes, power electronics that can operate faster, at higher temperatures, voltages and frequency. Fig. 10 shows micrograph of the film which was uniformly deposited. The XRD result showed that the film crystallized in cubic structure

## 6. CONCLUSIONS

Aluminum oxide thin film could be grown by solution growth technique. The film is a wide band gap semiconductor, with low absorbance, low reflectance, high transmittance and high refractive index. It is a cubic semiconductor crystal with optoelectronic application.

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