iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** I **Month of publication:** January 2020

DOI: http://doi.org/10.22214/ijraset.2020.1084

Al_2O_3 Thin Film as an Anti-Reflection Coating on Solar Cells

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***Abstract:** Al_2O_3 dense films using Al $(NO_3)_3 9H_2O$ and acetyl acetone (AcAc) were prepared by sol-gel method. Small amount of PVA is used as an anti cracking agent. The thin films fabricated onto a glass substrate by spin coating method after sintering at 600 ^{0}C for 2 h by changing the speeds such as 2000RPM, 3000RPM, 4000RPM and durations corresponding to those speeds such as 20Sec, 30Sec, and 40 Sec respectively. Atomic force microscope and field emission scanning electron microscope images of the films reveal a crack free surface and a dense cross-section. The films showed a band gap of 3.453 to 3.634 eV corresponding to speed and duration of the spin coater.*
***Keywords:** Anti-Reflection coating (ARC), sol-gel method, Spin coating .*

I. INTRODUCTION

Solar energy is the leading energy to satisfy the demands in recent years. Efficiency enrichment has been a significant task in recent time. Our goal is to achieve high efficient low cost and environmental friendly solar cells. A solar cell is a device which converts the energy from sun into electrical energy.

Silicon is a semi conductor optical material with relatively high refractive index. It is an ideal material for solar cells. When the light is incident on a solar cell about 35% of the incident light is reflected back [1]. In general, the optical losses account for about 7% efficiency loss in crystalline silicon solar cells [2].

The anti-reflection coating on the solar cell reduces the optical losses such as reflectance and increase the efficiency. The bandgap determines the wavelength at which photovoltaics operate more efficiently. Generally we use wide bandgap semiconductor materials as an anti-reflection coating on the solar cells. In this work we will see how Al_2O_3 can be used as an antireflection coating on the solar cells.

II. EXPERIMENTAL DETAILS

A. Raw-materials Required

Aluminium Nitrate nonahydrate [Al $(NO_3)_3.9H_2O$], Acetic acid [CH_3COOH], Acetyl Acetone[$CH_3C(O)CH{=}C(OH)CH_3$], PVA.

B. Sol-gel Method

1) *Synthesis Of Alumina Precursor Solution:* Initially, 0.05M Al $(NO_3)_3.9H_2O$ is dissolved in 100 mL of glacial acetic acid and stirred for 30 min. After stirring for 30 min, acetylacetone (AcAc) is added to the solution and the solution is stirred for another 30 min. Now, the colour of the solution changes from colourlessness to pale yellow. The molar ratios of AcAc to the Al $(NO_3)_3.9H_2O$ are is 4:1. At last, a small amount of polyvinyl alcohol (PVA) is added to the mixture solution and then drastically stirred for 6 h to obtain the target solution. The whole synthesis process is performed in 60^{o}C on magnetic stirrer. The resulting solution exhibits remarkable stability without any large physical change including colour, transparency and viscosity for several months at room temperature. [3]
2) *Coating Of Alumina Precursor Solution On Substrate:* In this work glass substrates are taken and are cleaned thoroughly by ultrasonication in acetone, ethanol and deionised water, successively .The spin coating technique is employed to coat the substrate at speeds of 2000 rpm,3000 rpm and 4000 rpm for different time intervals such as 20 sec,30 sec, 40 sec.

Finally, the samples are calcined at 600 ^{0}C for 2 h in a muffle furnace in air to form alumina thin films.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue I, Jan 2020- Available at www.ijraset.com

III. RESULTS AND DISCUSSIONS

A. Thin Film Thickness Measurement System

The thin film thickness measurement was done to glass slide coated with Al_2O_3 and the thickness of the coating is measured. The table below shows the values of thickness of the coating deposited on the glass surface at different speeds and duration.

Table 1: thickness of samples at different speeds and durations

	2000RPM	3000 RPM	4000 RPM
20 Sec	419.4 nm	322.2 nm	210.4 nm
30 Sec	426.1 nm	348.4 nm	330.7 nm
40 Sec	522.9 nm	422.8 nm	323.1 nm

B. UV-VIS-NIR Spectroscopy

The UV-VIS-NIR Spectroscopy was carried out on the Al_2O_3 coated glass slide and the values of the wavelength at which the absorption peak occurred has been noted.

The band gaps were also calculated for the same by using the formula.

$E = hc/\lambda$

Where E=band gap

h=Planck's constant

λ=wavelength at which the absorption occurred

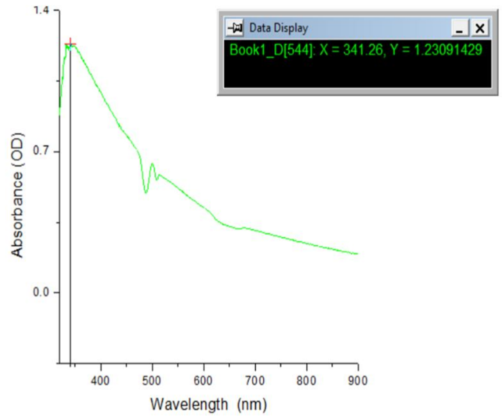

Figure 1 : graph at 2000RPM 20Sec

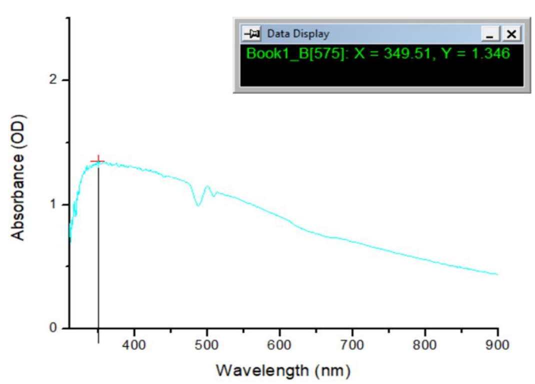

Figure 2 : graph at 2000RPM 30Sec

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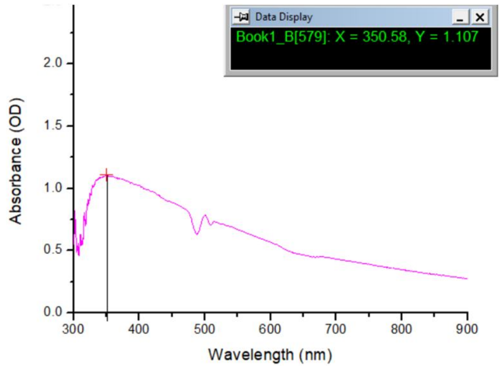


Figure 3: graph at 2000RPM 40Sec

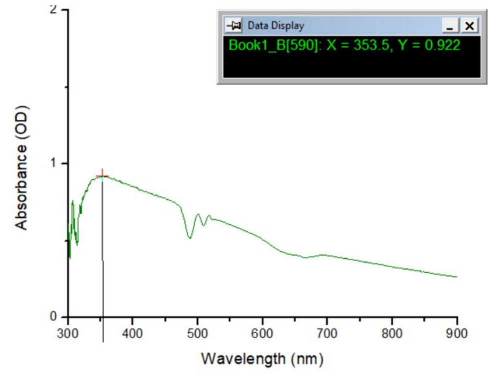


Figure 4: graph at 3000RPM 20Sec

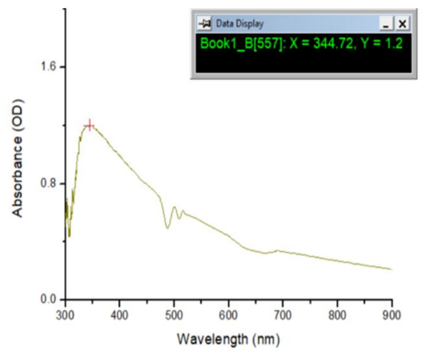


Figure 5: graph at 3000RPM

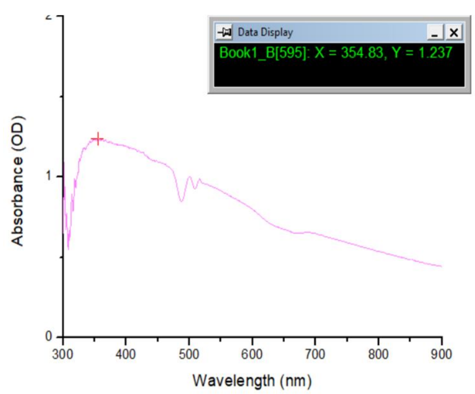


Figure 6: graph at 3000RPM 40Sec

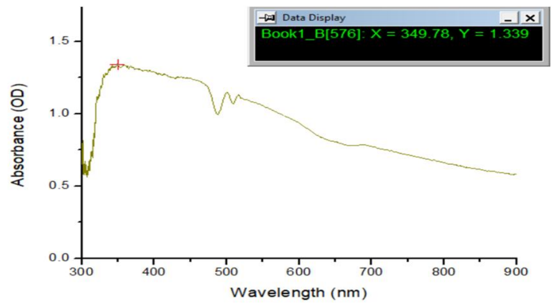


Figure 7: graph at 4000RPM 20Sec

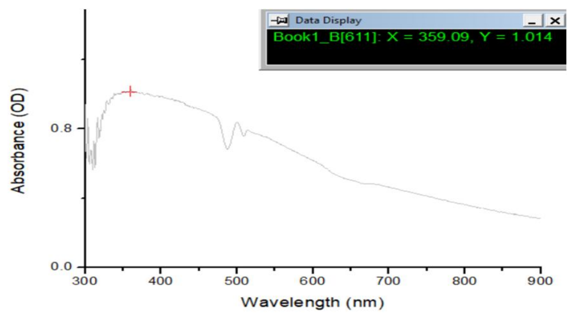


Figure 8: graph at 4000RPM 30Sec

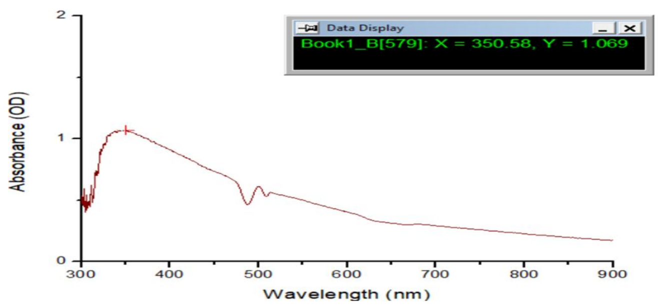


Figure 9: graph at 4000RPM 40Sec

Figures 1 to Figure 10 shows the absorption peaks at certain wavelengths. Now we will calculate the band gap using these values and formulate in the Table 2.
The Table 2 below shows the wavelength at which absorption peak occurred and corresponding band gap of the Al_2O_3 coated glass slides at different speeds and duration.

Table 2: wavelength and band gap of samples at different speeds and durations

peed(RPM)	2000 RPM		3000 RPM		4000 RPM	
Duration(Sec)	λ λ (nm)	Band gap E (eV)	λ λ (nm)	Band gap E (eV)	λ λ (nm)	Band gap E (eV)
20 Sec	341.26	3.634	353.50	3.508	349.78	3.546
30 Sec	349.51	3.548	344.72	3.597	359.09	3.453
40 Sec	350.58	3.537	354.83	3.494	350.58	3.537

From the tabular form we can infer that the band gap varies in between 3.453eV to 3.634eV.

C. EDAX Results

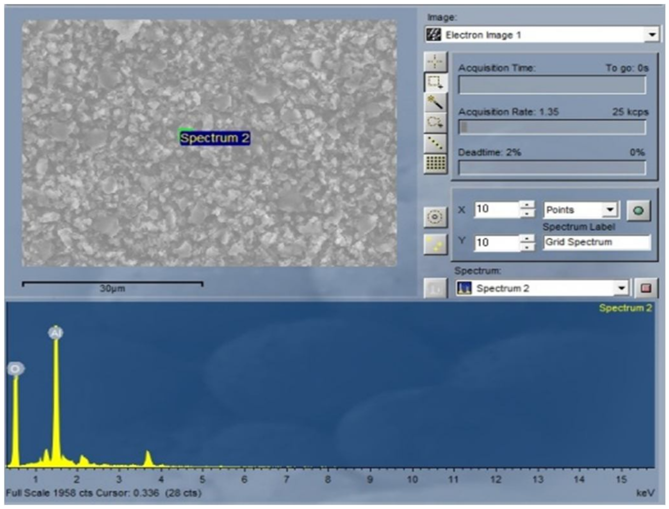
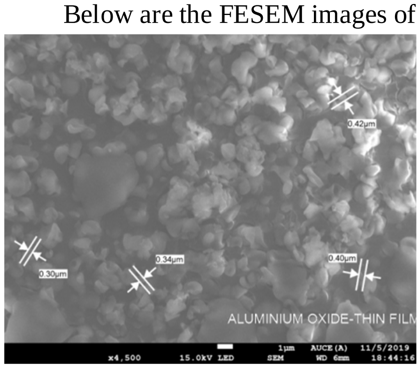


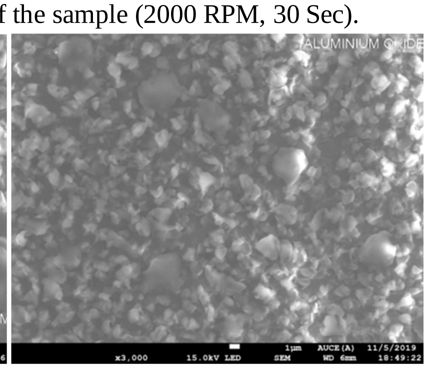
Figure 10: EDAX image of sample

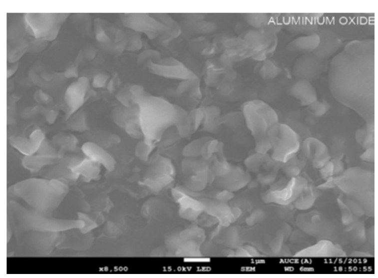
Figure 10 shows the EDAX image of the glass slide coated with Al_2O_3. From the figure we can infer that a small area of the sample is selected and is made to investigate the chemical composition. We see that sample contains the composition of aluminium and oxygen.

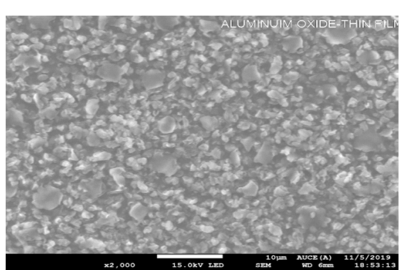
D. FESEM Results

Below are the FESEM images of the sample (2000 RPM, 30 Sec).









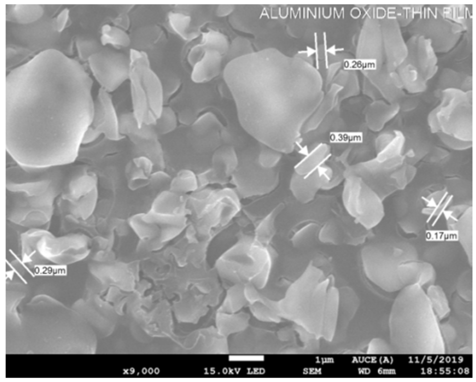


Figure 11: FESEM images of sample

From the FESEM images, we see the surface of the sample coated with Al_2O_3. We can see that the minimum particle size is 170nm.

E. AFM Results

Below are AFM images of the samples.

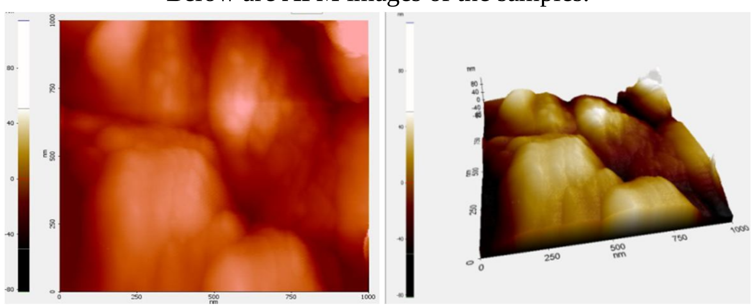


Figure 12: AFM image of sample (3000 RPM, 20Sec)

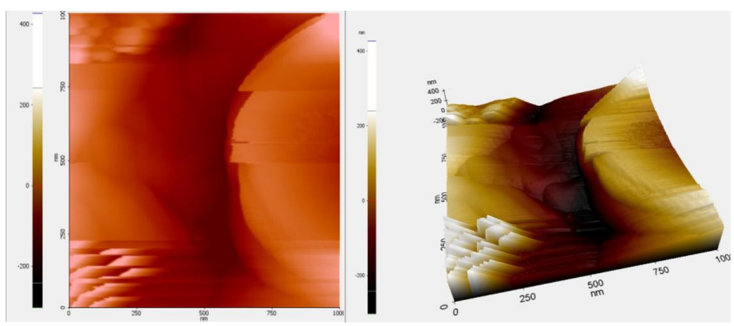


Figure 13: AFM image of sample (4000 RPM, 40Sec)

Table 3: Roughness parameters of the samples

Sample	Maximum Height(µm)	S_q(µm)	S_a(µm)
3000 RPM, 20Sec	0.1142	0.0259	0.0214
4000 RPM, 40Sec	0.4267	0.123	0.1061

Figure 12 and Figure 13 shows the AFM images of samples coated at 3000 RPM, 20 Sec and 4000 RPM, 40 Sec respectively. The table shows the maximum height , root mean square value of height (S_q), average height(S_a) of the samples.

IV. CONCLUSION

Al_2O_3 thin films were fabricated by using sol-gel spin coating method at 600^oC for different speeds such as 2000RPM, 3000RPM, 4000RPM and durations of 20sec, 30sec, 40sec. The thickness of the film is measured using thin film measurement system. The thickness was found to be in the range of 210.9nm to 522nm. The UV-VIS-NIR Spectroscopy was done and band widths were in the range of 3.453eV-3.634eV. The EDAX gave the result that the sample contains the composition of aluminum and oxygen. The FESEM and AFM characterizations are also done.

Hence we can conclude that due to the wide optical band gap and low absorption i.e. high transmittance in the visible region the Al_2O_3 can be used as an anti reflection coating application for the photovoltaics.

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