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DEPOSITION AND CHARACTERIZATION OF ALUMINUM (AL) AND ALUMINUM OXIDE (AL_2O_3) THIN FILM COATINGS USING PHYSICAL VAPOUR DEPOSITION METHODS

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Abstract

Thin film is a layer of material whose thickness range from fraction of nanometers to few microns. Thin film is usually deposited under vacuum or inert gas environment to avoid the impurities in the coating [1]. Properties of thin film coating depend on the deposition method employed. Hence selection of a deposition process according to specific application is necessary. Even if deposition parameters are maintained similar in different processes, the coatings show different behaviour because of different principles involved in deposition. This paper deals with deposition of Aluminium(Al) and Aluminium oxide(Al_2O_3) thin films using Thermal Evaporation, E-Beam Deposition and Magnetron Sputtering Processes on Borosilicate glass substrate and study of their Electromagnetic characteristics such as Reflectance, Transmittance and Absorptance, in the wavelength range of 250 nm to 2500 nm using UV-VIS-NIR Spectrophotometer and surface roughness by atomic force microscope . Samples were coated to 100nm thickness at room temperature using 99.999% Aluminium / Alumina targets, using all the three processes. It was observed that the sputtering process gave the reflectance while the evaporation process gave the best Transmittance.

Keywords: Thin film, Thermal Evaporation, E Beam-Deposition and Sputtering Process

1. Introduction

Thin film is a layer of material whose thickness range from fraction of nanometres to few microns. Thin film is usually deposited under vacuum or inert gas environment to avoid impurities in the coating [1]. Thin films have interesting properties that are quite different from those of the bulk materials of which they are made. This is because of the increasing surface to volume ratio at decreasing film thickness and macroscopic structure which depend on number of interrelated parameters, and also on the technique employed for their fabrication.

Purity of the target material, material and surface quality of the substrate used, degree of vacuum used inside the coating chamber, flow of the reactive. Gases during the film growth process, the rate of sputtering/evaporation are some of the important parameters that determine the mechanical, optical and other parameters of coated components. The main purpose of depositing thin film coatings on a surfaces is to modify it to provide environmental protection and improve performance.

1.1 Process used for thin film deposition

1.1.1 Physical vapor deposition

Physical vapor deposition is a process in which the material to be coated physically travels in the form of vapor or atoms on to a substrate and the condensate over the substrate forming the new structure.
Following are the few types of Physical vapor deposition processes

a. Thermal evaporation
b. E-beam deposition
c. Sputtering process

a. **Thermal evaporation:** The creation of the vapor of the material in Physical Vapor deposition process is accomplished by simple method such as resistive heating of material to be evaporated [2].

b. **E Beam deposition:** Electrons are generated by thermionic emission from a filament made of metal having high melting point which are directed to the target (charge). The filament is the cathode and water cooled target holder is connected to the anode. On supply of current, the E-Beam strikes the target, heating the charge and vaporising it.The vapours rise up and get deposited on substrates placed on a holder which is rotated. The rate of deposition and thickness can be controlled by varying the filament current [2].

c. **Sputtering:** It is carried out under vacuum condition. Target is connected to cathode and Substrate is connected to anode. Argon is made to flow into the vacuum chamber containing target and substrate. On applying power, argon is ionized creating plasma. These high energy ions upon hitting the target ejects atoms from it. The ejected atoms get deposited on the substrate surface [1].

The Reflectance of Aluminium is about 88-92 % in wide range Solar Spectrum but decrease a little in the visible region and reach maximum of (> 98%) in the infrared region. Alumina, as refectory oxide finds wide applications in engineering. It possesses very high dielectric constant which renders its use as a dielectric coating. Alumina can also be used for anti-reflection coating on camera spectacle lenses [2] [4]. From a review of available literature it was found that there is immense scope for developing processes for selective control of optical properties such as reflectance and transmittance

2. Experimental procedure

For all the three processes Borosilicate glass of dimensions 37*25*1.2mm was used as a substrate. It was prepared by following standard procedure of rinsing in water, cleaning in detergent solution rinsing in methanol/acetone, dipping in acqua regia (3:1 solution of HCL and HNO3). Thermal Evaporation and E-Beam Deposition machine (HHV BC-300T) was utilized to deposit aluminium and alumina on the prepared substrate. The deposition was carried in room temperature and process as peer parameters listed in tables 1 and 2. Sputtering machine (By HHV-Sara) was utilized to deposit aluminium and alumina on substrate by Sputtering Process according to process parameter listed in the tables 1.

Material	Process	Purity	Process Pressure in(mbar)	Substrate Rotation Speed (rpm)	Rate of Deposition (/Sec)	Thickness (nm)
Aluminium	Thermal Evaporation	99.999%	3.6×10^{-5}	10.5	5	100
	Sputtering Process	99.999%	6×10^{-3}	10.5	0.916	100
Alumina	E-Beam deposition	99.999%	3.6×10^{-5}	10.5	2.2	100
	Sputtering Process	99.999%	6×10^{-3}	10.5	0.147	100

(Table 1: Process Parameters used in physical vapour deposition)

3. Results and discussion

3.1. UV-VIS-NIR

The deposited film was characterized for UV-VIS-NIR by using the UV-VIS-NIR spectrometer (Perkin Emily Lambda 750). Transmittance and Reflectance values for the film were obtained for the wavelength range of 250 nm to 2500 nm and the values were plotted against their wavelength as shown in figures 1-6. Absorptance of film was calculated by using basic relationship

Absorption = 100 - Transmittance – Reflectance

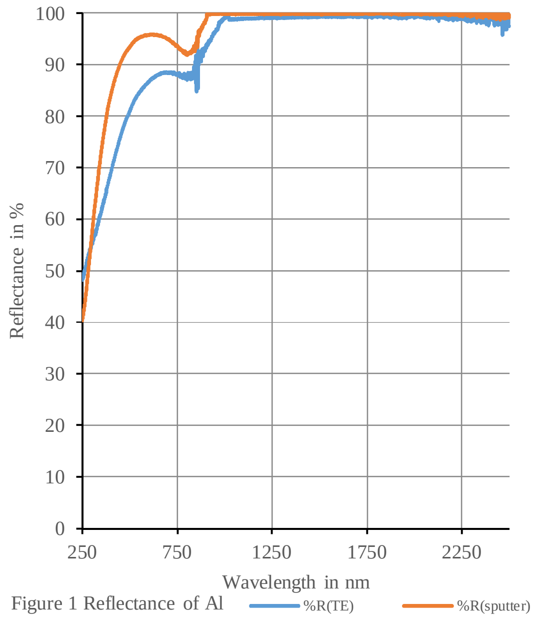

Figure 1 Reflectance of Al

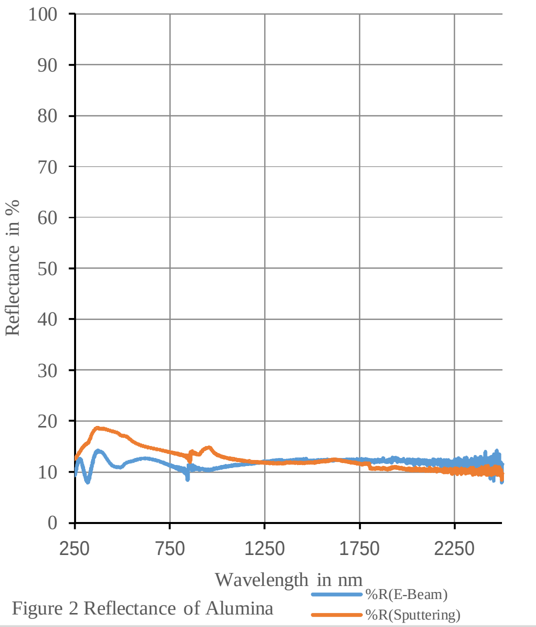

Figure 2 Reflectance of Alumina

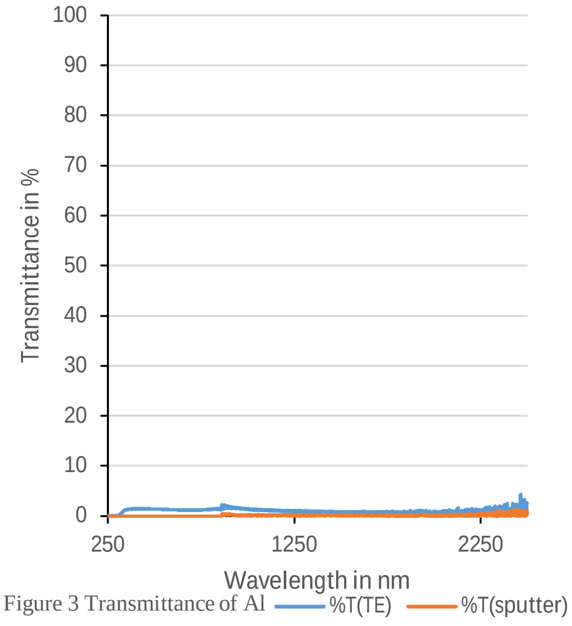

Figure 3 Transmittance of Al

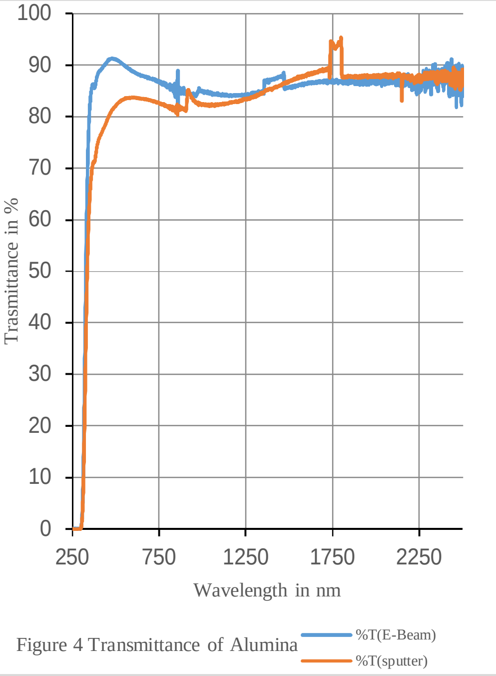

Figure 4 Transmittance of Alumina

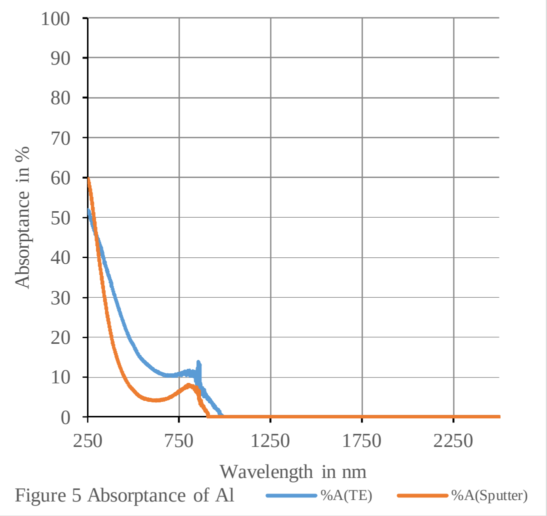

Figure 5 Absorptance of Al

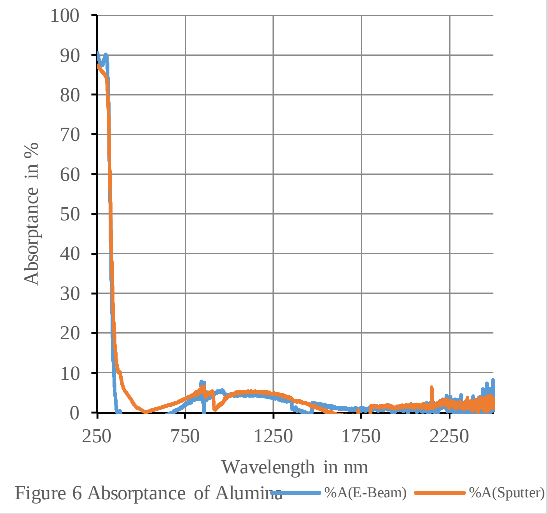

Figure 6 Absorptance of Alumina

The reflectance of Al deposited by sputter is found to be high in both in UV and Visible region compared to the Thermal Evaporation process but in infrared region both seems to be similar (Figure 1). Though the reflectance of Alumina is very low it is found to be constant, Sputter coated Alumina Shows a high reflectance compared to E-Beam Deposited sample (Figure 2). The Transmittance of Al is very negligible. Transmittance from Thermal evaporation process is high compared to that of Sputtering process (Figure 3). Transmittance of the alumina deposited by Sputter is also low compared to E-Beam deposition in Both UV and Visible region and in they coincide in infrared region (Figure 4). The absorptance of Al thin films coating is Considerable in the UV region and it is minimum. Maximum absorptance of the Al is achieved by thermal evaporation process compared to sputter (Figure 5). Absorptance of Alumina is high in the UV region and negligible in visible and infrared regions (Figure 6).

1.2 Surface roughness

Surface roughness of both aluminium and alumina coated samples for 100nm were measured using Atomic Force Microscope (AFM). For samples deposited by thermal evaporation process, , and Magnetron Sputtering Processes, cross section area of 25µm^2 was considered for measurement of surface topography. The roughness was measured along the diagonal of the sample area.

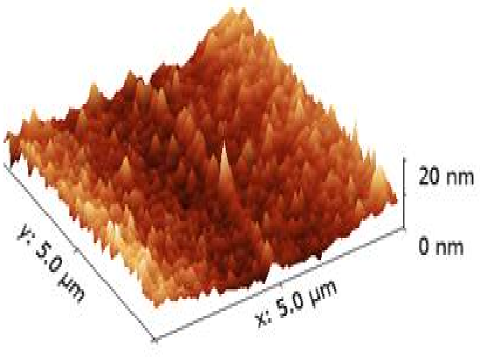

Figure 7 *3D* image of the 100nm aluminium thin film deposited by sputtering process

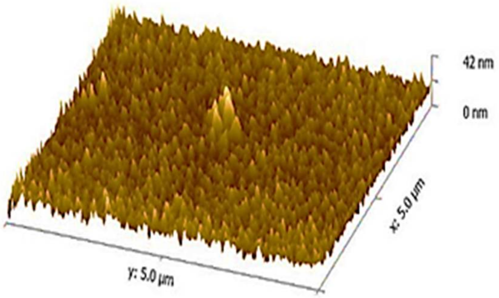

Figure 8 *3D* image of the 100nm aluminium thin film deposited by sputtering process

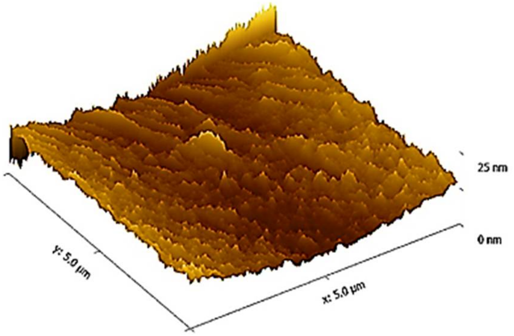

Figure 9 *3D* image of the 100nm alumina thin film deposited by sputtering process

	100nm Al by TE	100nm Al by SP	100nm Alumina by SP
Average value:	5.67 nm	2.10 nm	0.71 nm
Minimum:	0.00 nm	0.00 nm	0.00 nm
Maximum:	20.04 nm	14.66 nm	2.05 nm
Median:	5.34 nm	5.89 nm	1.75 nm
R_a:	1.87 nm	2.10 nm	0.71 nm
RMS:	2.35 nm	1.75 nm	0.87 nm

(Table 2: Surface roughness values of Physical vapor deposition)

Table 2 provides surface roughness values of the various deposition process for 100 nm thickness. The average surface values for aluminium coated films by sputtering process have lesser average surface roughness compared to thermal evaporation process.

4. Conclusions

1. The Transmittance values obtained for Alumina by Evaporation is high compared to Sputtering Process. Hence for applications requiring high transmittance, the evaporation methods can be used
2. The Reflectance values obtained for Aluminium by Sputtering Process is high compred to Evaporation. Hence for applications requiring high reflectance, the Sputtering process can be used.
3. It can be observed from table 2 the average surface roughness have direct influence on the UV-NIR-VIS characteristic of a thin film since sputtering process have less surface roughness compared to thermal evaporation process the reflectance for aluminum thin flim deposited by sputtering is more compared to the thermal evaporation.

5. Acknowledgement

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A Brief Author Biography

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