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Deposition Angle as an Important Factor on Structural Changes of Thin Films

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ABSTRACT

Aluminum oxide thin films of 67 nm thickness at two different deposition angles of 20 and 50 degrees were deposited on glass substrates at room temperature, by using resistive evaporation method under Ultra High Vacuum (UHV) conditions. The structural details were determined by AFM and SEM methods. The optical spectra were measured by spectrophotometer in the spectral range of 300-1100 nm wave length (UV-Vis). The relation between nanostructures and optical properties with deposition angle were discussed.

Key words: Aluminum oxide, AFM, SEM, spectrophotometer

INTRODUCTION

Al₂O₃ is generally recognized for its high dielectric constant, high band gap, transparency, nontoxic nature, high refractive index and no significant absorption in the visible part of the solar spectrum. Alumina (Al₂O₃) thin films are widely used as, wear resistant or diffusion barrier coatings (Thongkham *et al.*, 2010). Amorphous Al₂O₃ films also represent one of the most successful materials widely used as a gate dielectric in Organic Thin Film Transistors (OTFTs) (Ha *et al.*, 2002).

The nanostructure of thin films is strongly affected by film preparation procedures and deposition condition. For example substrate temperature, angle of incidence, deposition rate and film thickness have important effects on the morphology and nanostructure of thin films. The previous studies have indicated that the properties of the Al₂O₃ films depend on the film thickness (Kumar *et al.*, 2009) and the growth temperature (Min *et al.*, 2005).

The Al₂O₃ thin film can be prepared by various methods such as, molecular beam epitaxy, Chemical Vapor Deposition (CVD) (M'Saoubi and Rупpi, 2009), Plasma Enhanced Chemical Vapor Deposition (PECVD) (Chryssou and Pitt, 1997), reactive sputtering (Andersson *et al.*, 2006; Ha *et al.*, 2002; Voigt and Sokolowski, 2004), Atomic Layer Deposition (ALD) (Min *et al.*, 2005; Kim *et al.*, 2006; Zhang *et al.*, 2009; Groner *et al.*, 2004) and spray pyrolysis (Esparza Garcia *et al.*, 1999).

The aim of this research is to study the effect of deposition angle on structural properties of Al₂O₃ thin films.

MATERIALS AND METHODS

Aluminum oxide films were deposited on glass substrates (18×18×1 mm, cut from microscope slide) by using resistive evaporation method, from tungsten boats, at room temperature, of 2 different deposition; 20 and 50 degree deposition angles. The evaporated materials were pieces

of aluminum oxide. An ETS 160 (Vacuum Evaporation System) coating plant with a base pressure of 3×10^{-5} mbar was used. Prior to deposition, all glass substrates were ultrasonically cleaned in heated acetone first and then in ethanol. The substrate holder was a disk of 36.5 cm in diameter with adjustable height up to 45 cm and also adjustable holders for placing any kind of substrates. Thicknesses of layers were determined by quartz crystal microbalance technique. Thickness of layers was 67 nm. The other deposition conditions such as deposition rate, vacuum pressure and substrate temperature were the same in all tests. The surface physical morphology and roughness were obtained by means of AFM (Dual Scope™ DS 95-200/50) analysis. Scanning electron microscopy method used for determining nanostructure of layers. The transmittance of films was measured using UV-Vis spectrophotometer (Hitachi U-3310) instrument. The spectra of layers were in range of 300-1100 nm wavelength (UV-Vis).

RESULTS AND DISCUSSION

Figure 1 show, three dimensional AFM images for $\text{Al}_2\text{O}_3/\text{glass}$ layers, of the same thickness ($d = 67$ nm) at two different deposition angles, as 20 and 50 degree.

Figure 1a shows morphology of layer with 20 degree deposition angle, As it can be seen almost all the surface is covered with small grains and in some areas, bigger domed grains formed and layer is not smooth enough but its almost homogenous. By increasing deposition angle to 50 degree the grain's size increases with formation of more voids between them (Fig. 1b) and as it can be seen,

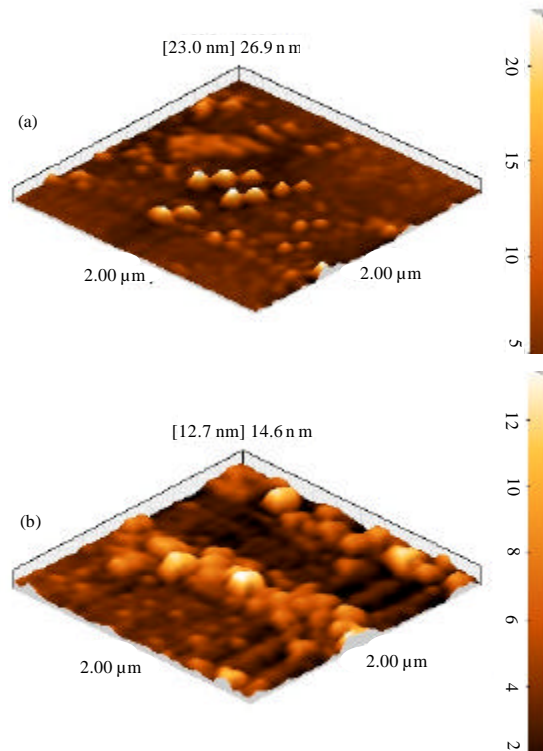


Fig. 1(a-b): AFM images of layers with, (a) 20 degree deposition angle and (b) 50 degree deposition angle

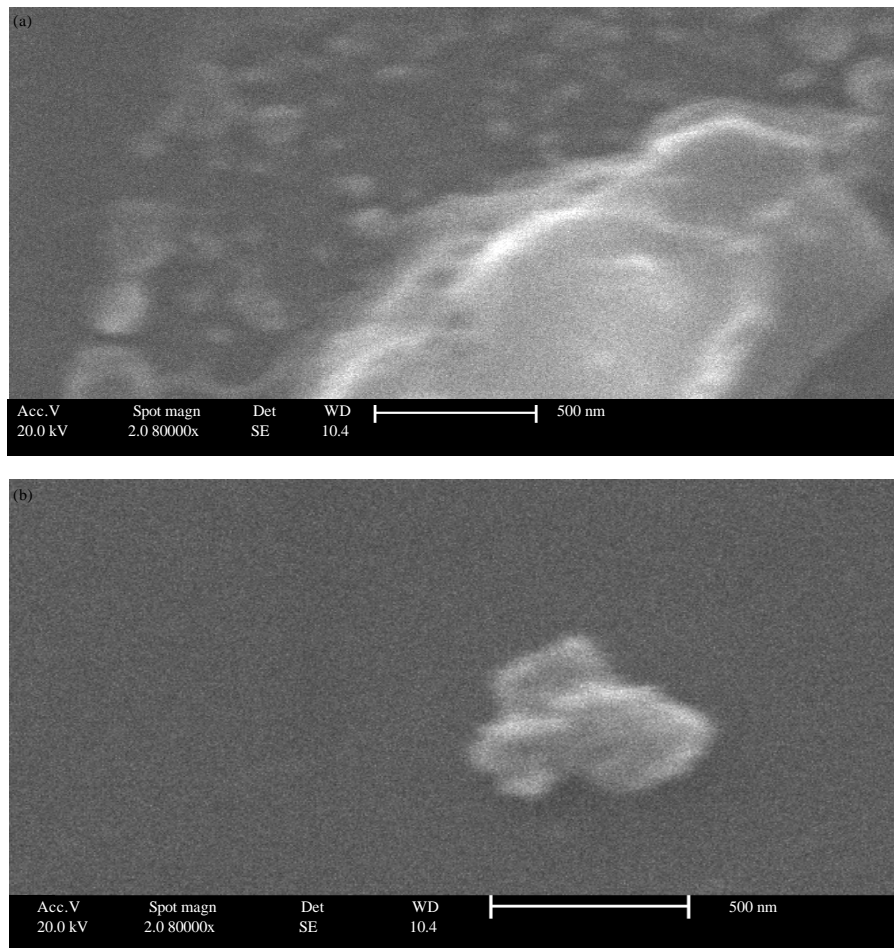


Fig. 2(a-b): SEM pictures of layers with, (a) 20 degree deposition angle and (b) 50 degree deposition angle

some kind of nano-sculptures has been formed and roughness decreases because there are many domed grains on surface and we are encountered with a heterogeneous layer.

Figure 2 shows SEM pictures of the layers produced in this study. Figure 2a depends to 20 degree and Fig. 2b depends to 50 degree deposition angles. As it can be seen from SEM images, for layer with 20 degree deposition angle, almost grains of aluminum oxide have covered all the substrate there are less voids on surface. But for layer with 50 degree deposition angle almost surface is empty and substrate is shown very clearly and there are a lot of voids on surface. Figure 3 shows transmittance curves for the layers produced in this study, as it can be seen by increasing deposition angle because of formation more voids on layer (in agreement with SEM and AFM results) transmittance increases so Fig. 3a shows less values than Fig. 3b. The percent of Transmittance is very high, up to 90 for 20 degree and up to 93 for 50 degree deposition angles, which is because of nanometric thickness of produced layers.

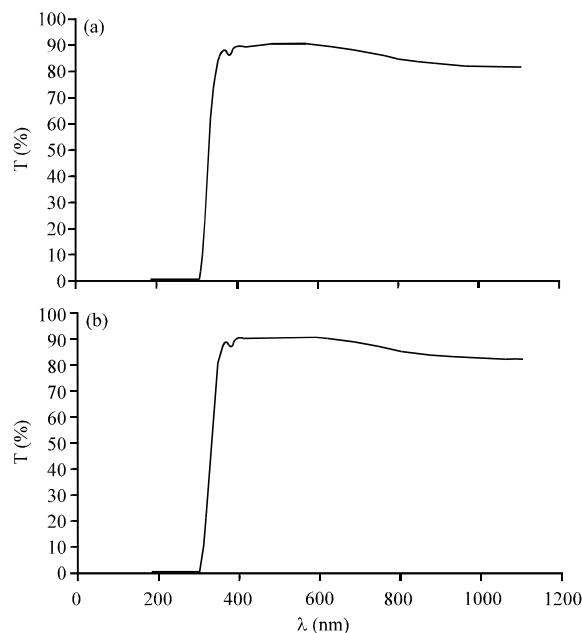


Fig. 3(a-b): Transmittance curves of the layers with, (a) 20 degree deposition angle and (b) 50 degree deposition angle

CONCLUSION

Aluminum oxide thin layers of 67 nm thickness were produced, by using resistive heat deposition of pieces of Al_2O_3 at 300 K temperature. Aluminum oxide thin films were transparent in visible light wavelength range. There was a good agreement between voids on layers for optical transmittance and structural properties. By increasing, deposition angle, more voids formed on layers that tend to production of heterogeneous layer. Optical and structural properties of the layers produced in this work, were in agreement with each other. Deposition angle is an important factor for changing structure of thin films and it is one of main factors for producing nano-sculptures and heterogeneous thin layers.

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