SURFACE MORPHOLOGY OF MgF_2/YF_3 MULTI LAYER THIN FILMS BY THERMAL EVAPORATION METHOD

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Abstract

Magnesium fluoride and Yttrium fluoride antireflection multilayer thin films have been deposited on to well cleaned BK-7 Glass substrate in Vacuum of $2x10^{-5}$ *mbar using physical vapour deposition technique. Surface morphology analysis by AFM of different multilayer structures deposited by thermal evaporation method i.e., Single layer, double layer, three layer and four layer thin films were presented in this study. The main objective of this study was to investigate the influence of thickness of various antireflection multilayer thin films on the effect of surface roughness and grain size of the particles. The thickness of the films has been determined by quartz crystal monitor method. The surface morphology studies are performed using Atomic force Microscopy (AFM) techniques. AFM was the best tool to investigate the surface smoothness and to find the grain size of the particles. The grain size is calculated for all the films of different thickness.*

Index Terms: *Multilayer's, AFM,* MgF_2/YF_3*, Roughness, Grain size, BK-7, Antireflection*

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1. INTRODUCTION

Magnesium fluoride (MgF2) and Yttrium fluoride have been extensively used as an antireflection coating materials due to their high transmittance in a wide wavelength range. Antireflection coatings with reduced surface reflection have attracted much more interest in the application of optical and electro optical devices such as photovoltaic cells, solar collectors, high power laser windows, camera lenses, display windows and IR diodes [1]. Most important are in optical instruments such as eye glasses, picture framing, show-case, Data display and television screens. A wide band AR coating uses multilayer stacks of alternating high and low refractive dielectric thin films deposited on the surface of the substrate. Various methods are used to deposit multilayer (MgF_2/YF_3) thin films [2]. Ion assisted deposition has recently been used to grow dense low absorption films of MgF_2 at reduced growth temperatures for optical application. The methods of growth include evaporation.

Physical Vapour Deposition (PVD) is the preferred coating method for small scale application. PVD process consists of different coating techniques [3]. Among these, the vacuum evaporation technique is an attractive, effective method and the application at enable the deposition of thin films of larger area with good uniformity. Deposition of film from the vapour phase involves necessary chemical reaction e.g., to form oxide thin films, the physical properties of vaporization, condensation, nucleation and growth which have been discussed by various authors in many monographs. Orientations are also those which determine the structure and microstructure of the obtained deposit i.e. its degree of crystallinity, its orientation, its chemical purity, its surface morphology, and its optical, electrical and mechanical characteristics –that is to say all properties it is desire to confer on the glass substrate unit together with thin films. Atomic force microscopy is an excellent tool to study morphology and texture of thin film surfaces [4]. In the present study, the variation of surface morphology of thermally evaporated multilayer thin films of MgF_2/YF_3 with single layer, double layer, three layer and four layer were studied at room temperature.

2. EXPERIMENTAL PROCEDURE

MgF_2 and YF_3 were used as antireflection coating materials for low, medium and high index materials on the cleaned BK-7 glass substrate. The cleaned substrates were placed in a selected holder. A cleaned molybdenum basket is filled with small (1.5 to 3.5mm) granules of MgF_2 material of purity 99.99% and placed in the electrical spiral heater of the coating unit, and one more cleaned molybdenum boat is filled with small (0.2 to 5mm) granules of YF_3 material of purity 99.99% and placed in the electrical spiral heater of the coating unit for second source of material. The vacuum chamber pumped down to $2x10^{-5}$ mbar. The boat and basket temperatures were gradually raised in steps according to a certain regime, alternatively. Thin films of different multilayer structures were prepared under the same evaporation conditions with a deposition rate of 1A°/sec. The pressure was obtained by diffusion pump by rotary pump in the coating unit and was measured using Pirani and Penning gauge. A rotary device was employed to maintain uniformity in films thickness. A substrate heater arrangement was employed to grow the thin films at different substrate/heater temperature. In this case, the substrate temperature was kept at 300ºC. The thin film thickness was measured with the in-situ quartz crystal monitor. The thickness of the single layer antireflection (MgF_2) was 123nm, the thickness of double layer antireflection thin film (MgF_2/YF_3) was 236nm, the thickness of three layer antireflection thin film ($MgF_2/YF_3/MgF_2$) was 359 nm, and the thickness of four layer antireflection thin film ($MgF_2/YF_3/MgF_2/YF_3$) was 473 nm. The surface morphology and grain size of different multi layer structures were measured at room temperature by the conductive Atomic force Microscopy (C-AFM) SPI 3800 probe station (SII Inc. Japan).

3. RESULTS AND DISCUSSION

The surface morphology of the different layered structures prepared at room temperature was analyzed by Atomic force Microscope. Fig.1 (a) and Fig. 1(b) shows the 2d and 3d images of BK-7 glass substrate. Roughness, RMS roughness and grain size of the thin films were investigated using AFM images [5-8]. The average surface roughness is given by 8.86nm and the RMS value is measured as 1.17nm.

Table-1: shows the Surface roughness of MgF_2/YF_3 multilayer thin films on BK-7 glass substrate

Layer Structure	Thick-Ness	Roughness (Ra)(nm)	RMS Rough ness (nm)	Grain size (nm)
Uncoated glass	3mm	8.86	1.17	2.235
Single layer	123nm	1.13	1.26	1.222
Double layer	236nm	3.11	4.26	9.365
Three layer	359nm	2.57	3.89	1.402
Four layer	473nm	2.22	2.99	3.167

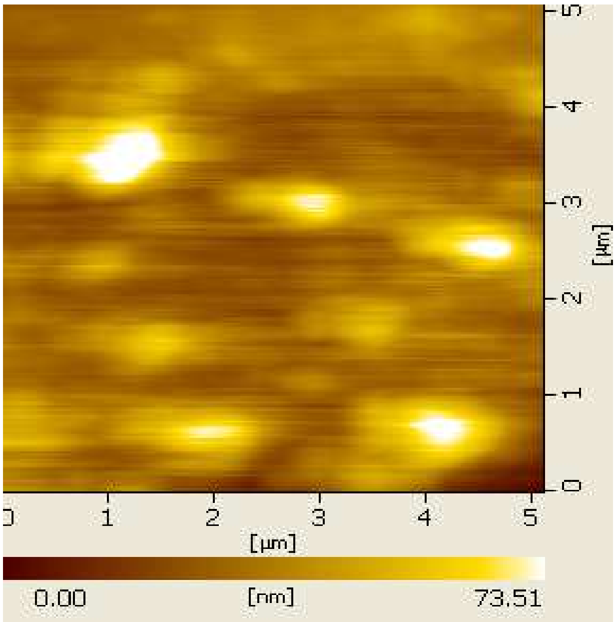

Fig. 1(a) Two dimensional AFM image (5 X 5µm) of the surface of bare BK-7 glass substrate.

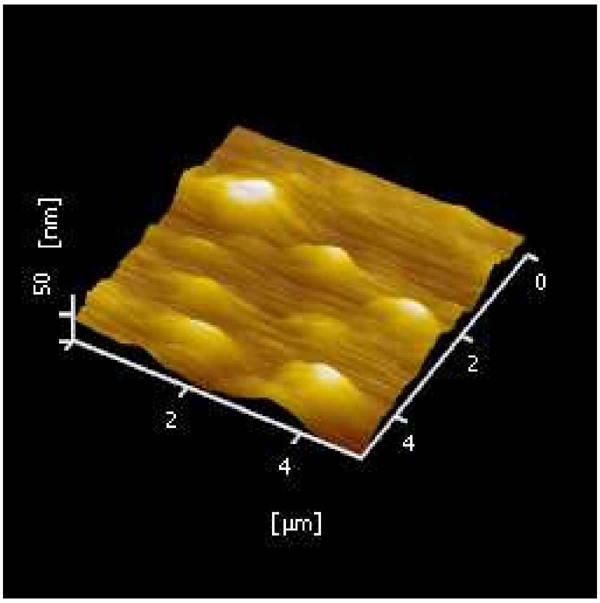

Fig. 1 (b). Three dimensional AFM image (5 X 5µm) of the surface of bare BK-7 glass substrate

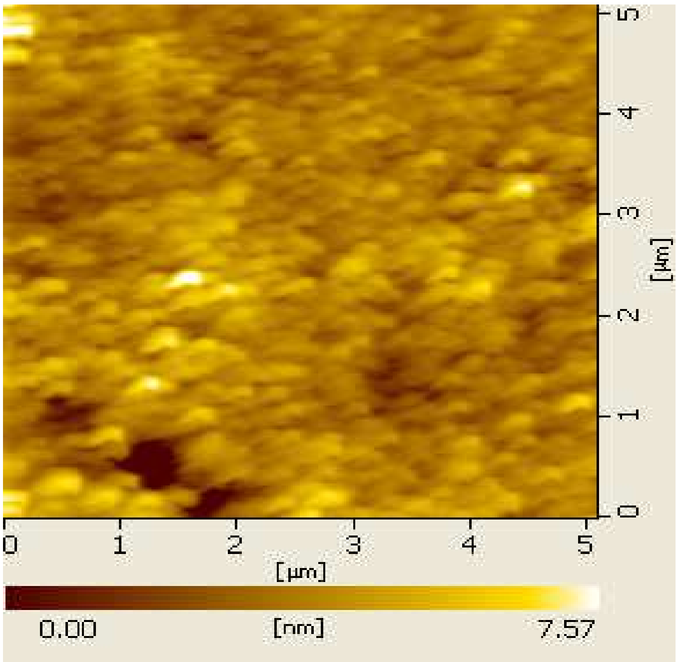

Fig. 2. (a) Two dimensional AFM image (5 X 5µm) of Single layer MgF2 thin film with the thickness of 123nm.

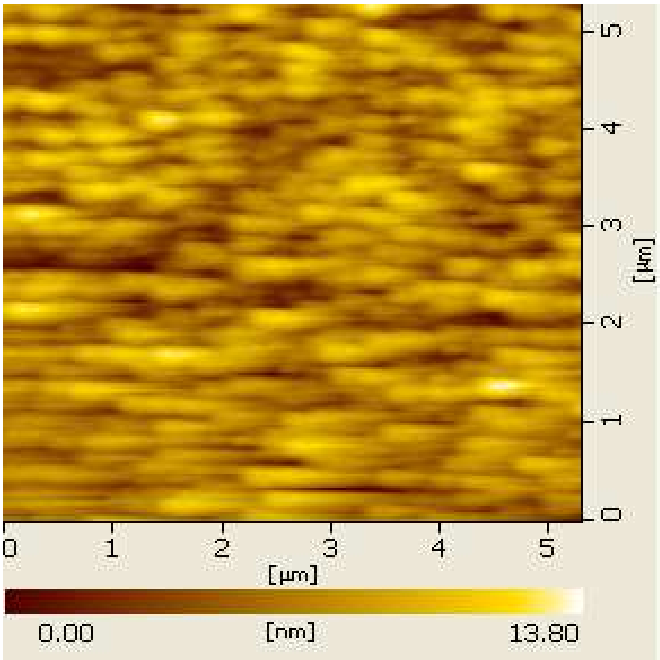

Fig. 3. (a) Two dimensional AFM image (5 X 5µm) of Double layer MgF2and YF3 thin films with the thickness of 236 nm.

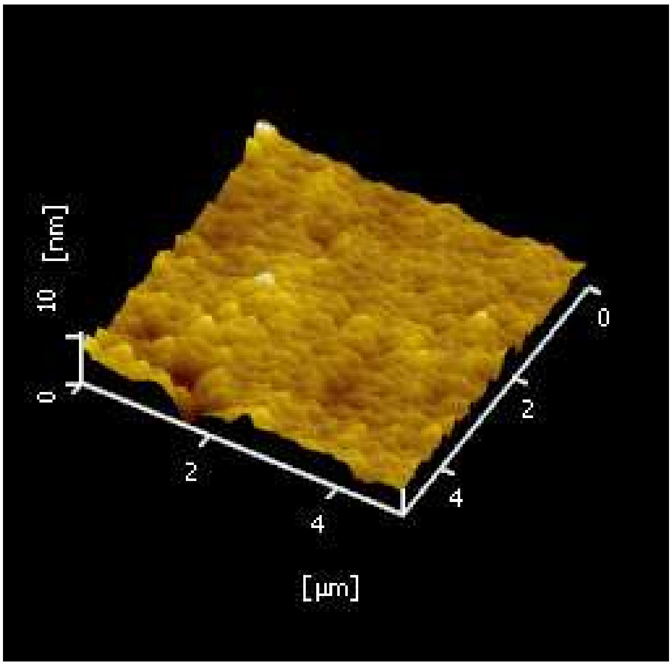

Fig. 2. (b) Three dimensional AFM image (5 X 5µm) of Single layer MgF2 thin film with the thickness of 123nm.

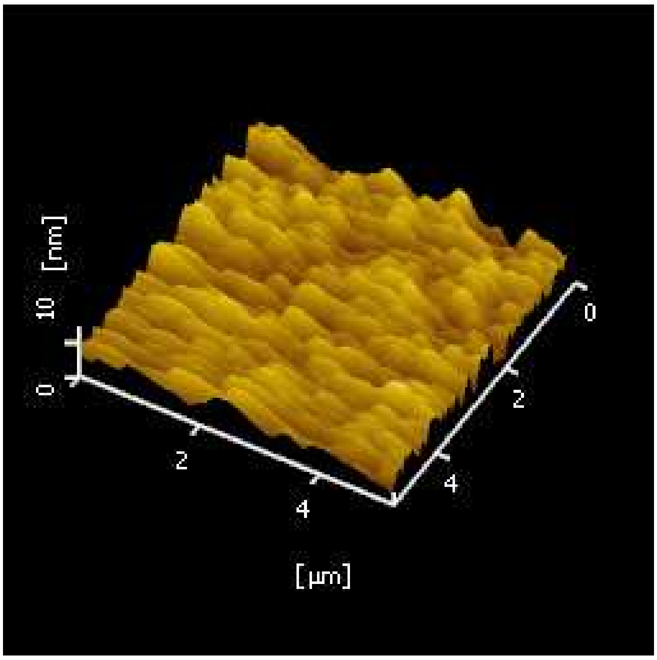

Fig. 3. (b) Three dimensional AFM image (5 X 5µm) of Double layer MgF2and YF3 thin films with the thickness of 236nm.

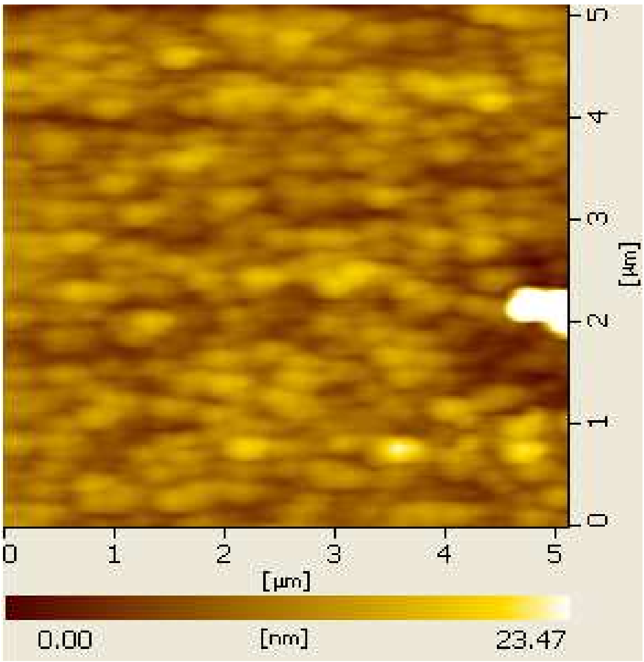

Fig. 4.(a) Two dimensional AFM image (5 X 5µm) of Three layer MgF2- YF3and MgF2 thin films with the thickness of 359nm.

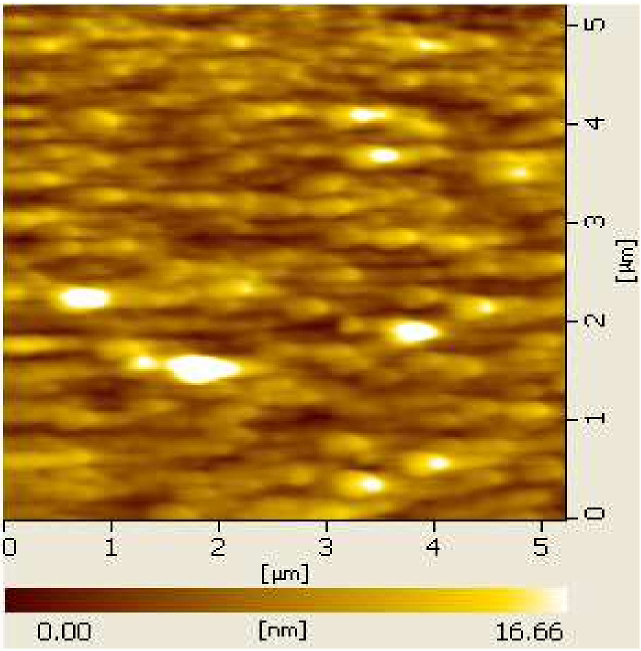

Fig. 5. (a) Two dimensional AFM image (5 X 5µm) of Four layer MgF2-YF3-MgF2-YF3 thin films with the thickness of 473nm.

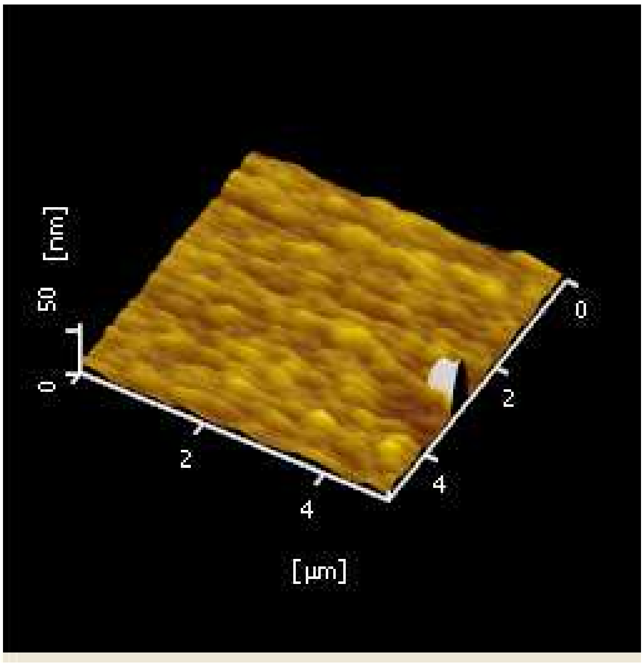

Fig. 4. (b) Three dimensional AFM image (5 X 5µm) of Three layer MgF2-YF3 and MgF2 thin films with the thickness of 359nm.

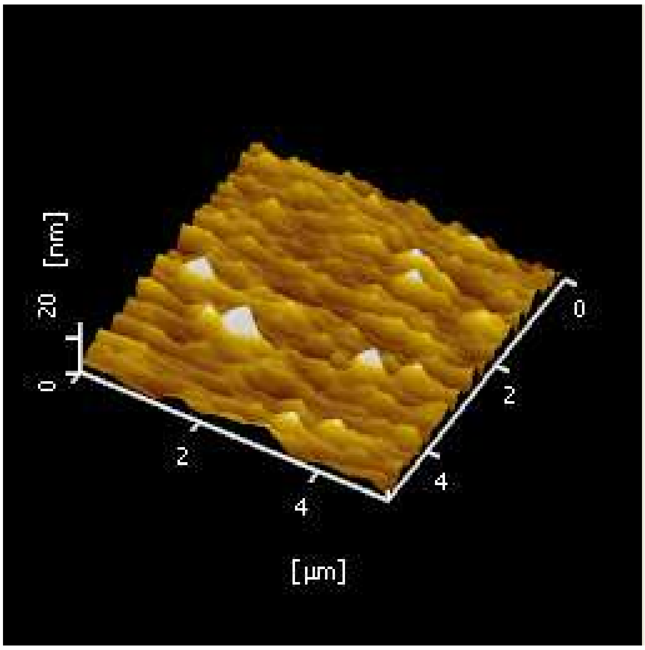

Fig. 5. (b) Three dimensional AFM image (5 X 5µm) of Four layer MgF2-YF3-MgF2-YF3 thin films with the thickness of 473nm.

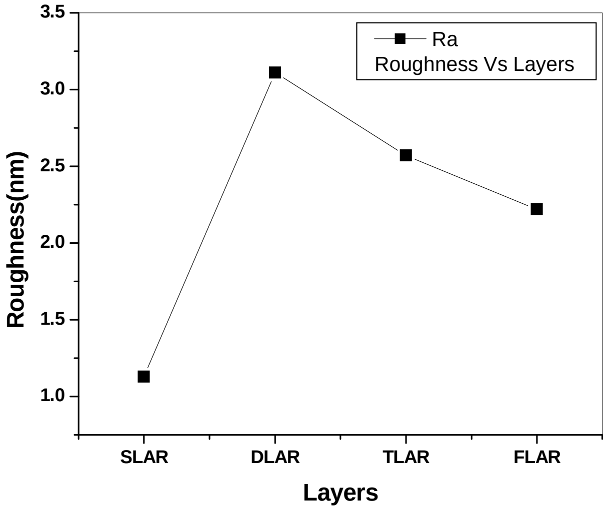

Fig.6.shows the variation of roughness Vs different layer structures

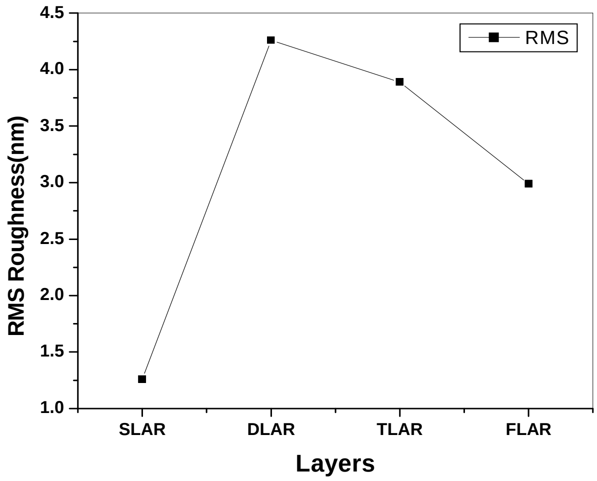

Fig.7. shows the variation of RMS roughness Vs different layer structures

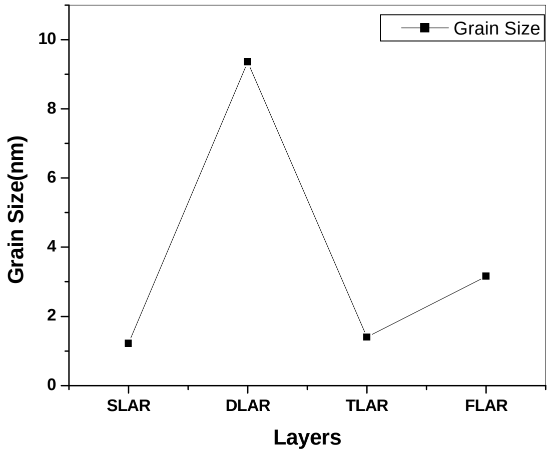

Fig.8 shows the variation of Grain size Vs different layer structures

Fig. 1(a-b) presents the 2-D and 3-D atomic force microscopy images of BK7 bare substrate. Paragraph comes content here. Initially MgF2 is coated on the substrate and AFM images were recorded in 2-D and 3-D as shown in Fig. 2(a-b). Roughness and RMS roughness were improved by coating single layer. Grain growth and larger grains with increase of the thickness of the film resulted in higher RMS roughness. Fig. 3(a-b) to Fig. 5(a-b) shows two dimensional and three dimensions AFM images of multilayer thin films from thickness 236 to 473 nm.

The two-dimensional and three-dimensional AFM images (5 X 5μm) shows that surface roughness and RMS roughness increased with increase of the thickness of the film from single to double layer as shown in Fig. 6. Further increase of thickness of the thin film resulted in decrease in roughness Ra and RMS roughness from double layer to four layered thin film of thickness 473nm as shown in Fig. 7. Initially grain size increases with the increase in the thickness of the thin film and then decreased with further increase of thickness to 473nm. The films grown are uniform and adhered the substrate well. The deposited multilayer film thickness has a great effect on the grain size of the thin films. It is clearly seen that the grain size is relatively larger in size for double layer thin film and comparatively rough than that of other multilayer thin films.

CONCLUSIONS

Multilayer MgF_2/YF_3 thin films of various thickness were prepared using physical vapour deposition technique. The versatility of this technique promoted a detailed observation of roughness and grain sizes of the thin films. AFM images indicate that regular, homogeneous surface and variable grain size was obtained with increase in thickness.

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REFERENCES

[1]. H.K. Pulker, Appl. Opt. 8 (1979) 1969

[2] J.J. Weimer, J. Kim, M. Zukic, D.G. Ton, J. Vac. Sci. Technol. 13 (1995) 1008

[3] D. Jacob, F. Peiro, E. Quesnel, D. Ristau, Thin Solid Films 360 (2000) 133.

[4]. MKwoka, L Ottaviano and J Szuber, Thin Solid Films 515 (2007) 8328

[5]. J.M. Bennett, J. Jahanmir, J.C. Podlesny, T.L. Balter, D.T. Hobbs, Appl. Opt. 34 (1995) 213.

[6]. Jiang, T., Hall, N., Ho, A., Morin, S., Thin Solid Films 417 (2005) 76–85

[7] Murakami, K., Nakajima, K., Kaneko, S., Thin Solid Films 515 (2007) 8632–8636

[8] Cheng, S., He, Y., Chen, G., Cho, E.C., Conibeer, G., Surf. Coat. Technol. 202 (2008) 6070–6074

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