Deposition, Optical Characterization and Durability Tests of MgF_2 Antireflection Thin Films

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***Abstract*— In this study, structural and optical properties of MgF_2 thin films produced by physical vapour deposition technique on the BK7 glass substrate have been investigated. Deposited films were annealed at different temperatures. Crystallinity in the material is confirmed by X-ray diffraction technique. Microstructure of the films shown uniform grain morphology. The optical properties have been investigated by using UV/VIS /NIR spectrophotometer. The optical constants of the films are in good agreement with the literature data of bulk MgF2. The durability of the coating has been systematically investigated by different treatments.**

***Keywords*— MgF_2 thin film, PVD, transmission, XRD, Durability tests.**

I. INTRODUCTION

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 [1-4]. AR coating on optical substrates have been carried out using various deposition techniques such as sol–gel, chemical vapour deposition (CVD.) etc. [5] and it has been shown that optical properties of thin films for AR coatings depend on deposition conditions and deposition technique [6]. The antireflection film formation method, which can be carried out more simply than the surface texturing method, applied to almost all solar cells. A very low refractive index film can be advantageous for AR coatings. Magnesium fluoride is commonly used for single layer quarter wave anti-reflection coatings because of its almost ideal refractive index (1.38 at 550nm) and high durability. It is the most widely used thin film material for optical coatings. Because of the wide transmission range, MgF_2 is an excellent coating material in UV wavelengths [7-8] its refractive index is too high to provide a good impedance match at the air-glass interface. We therefore investigated the effect of anti-reflection AR coating on a polished BK7 substrate to determine the improvement in transmission. In this paper, we present the deposition of MgF_2 films of optical quality by means of physical vapour deposition technique.

II. EXPERINMENTAL

MgF_2 has a high penetration ratio in a wide wavelength range from the 120nm ultraviolet ray in a vacuum to the 900nm infrared ray. Commercially available MgF_2 was used as antireflecting material. Ultrasonically cleaned BK7 glass was used as substrate. The deposited films were thermally heat treated at 400°C and 500°C and the Crystallinity in the material was measured by XRD. Microstructural analysis of deposited and thermally heat treated films was carried out using SEM. Optical property characterization of the un-coated and coated films was done by UV-Visible-NIR spectrophotometer.

III. RESULTS AND DISCUSSION

The XRD results for MgF_2 films that were grown on substrate and heat treated at different temperatures are illustrated in Fig. 1. MgF_2 films grew in an amorphous state at RT and as the substrate temperature increased above 300°C, MgF_2 films showed 110 preferred orientations. One can see that as the substrate temperature increases, the strength of the peak gradually increases. It appears that the MgF_2 was crystallized at 400°C & 500°C.

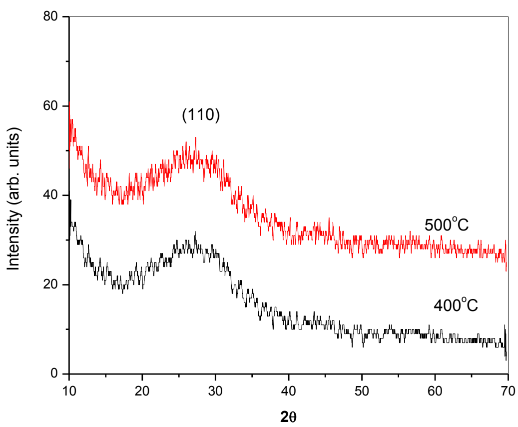


Fig. 1 XRD patterns of MgF_2 thin films annealed at different temperatures

A SEM photographic image of MgF_2 films is shown in Fig. 2 for the various growth temperatures. Surface uniformity was improved with the temperature. The higher the temperature of the heat treatment, the greater the grain size. The condition of the surface of the thin film got much better at a substrate temperature of 200°C. However, it was observed that the surface of the MgF_2 thin film got rougher at 300°C.

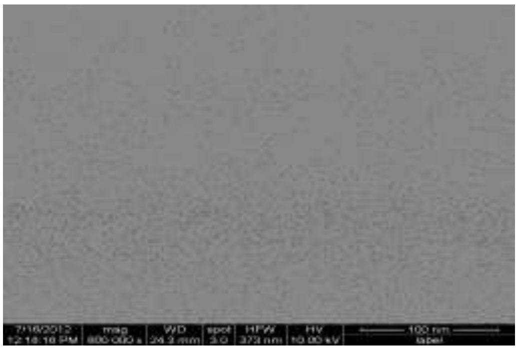


Fig (a)

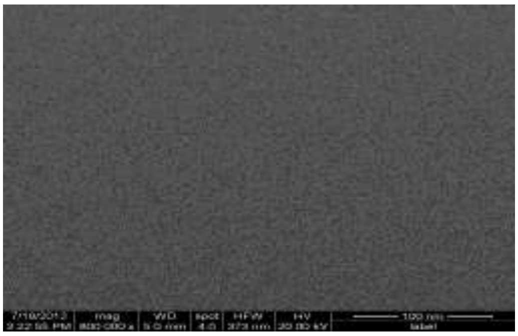
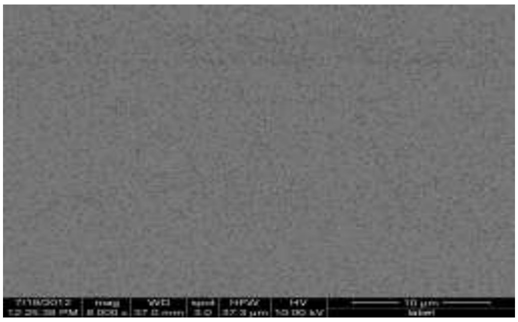


Fig (b)



Fig(c)

Fig. 2 (a-c) Scanning Electron Micrographs of MgF_2 thin films of RT and annealed at different temperatures.

Transmittance spectra of produced MgF_2 thin films are compared with the spectra of uncoated glass samples. The transmittance of the samples coated with MgF_2 is higher than that of uncoated samples. The transparency of MgF_2 thin film is 93.6% at 684 nm and it is in good agreement with the literature.

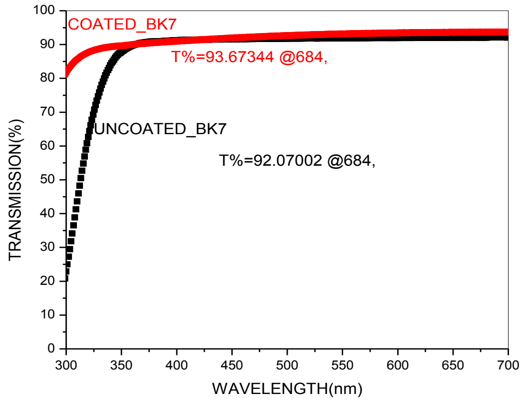
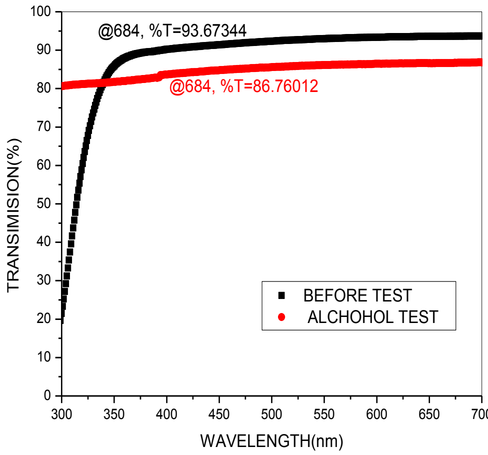
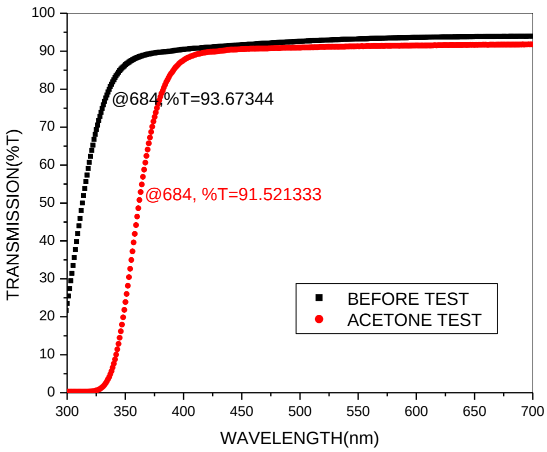


Fig. 3 Transmission spectra of uncoated BK7 and MgF_2 coated BK7 substrates



Fig(a)



Fig(b)

Fig. 4(a-b) Transmission spectra of durability test of MgF_2 films with alchohol and acetone solutions

Durability test of the coated MgF_2 thin films in alchohol and acetone tests. Transmission has decreased from 93% to 86% percent in alchohol test. Whereas Transmission effect is minimum in the case of acetone test. The transmission has decreased from 93% to 91%.

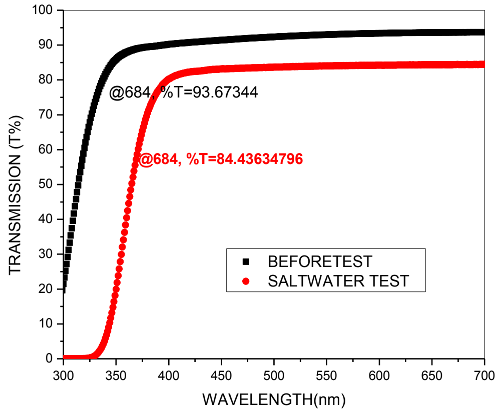


Fig.5.shows the Transmission spectra of MgF_2 thin films before and after durability test by salt water.

The effect of salt water on the transmission of MgF_2 thin film is shown in Fig. 6. Transmission is found to decrease from 93% to 84% by dipping the film in salt water.

The effect of temperature test (-54°C to +71°C) and the effect of boiled water (immersion in 24 hours) on the transmission of MgF_2 thin film is shown in Fig.7. Transmission is found to decrease from 93% to 92% by the temperature test and Transmission is found to decrease from 93% to 92% by the dipping the film in boiled water.

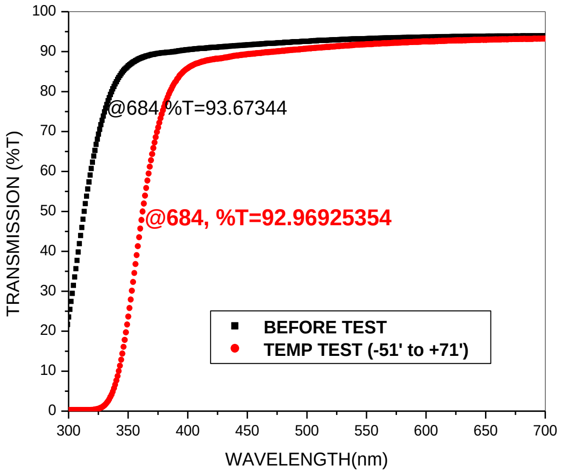


Fig.6 shows the Transmission spectra of MgF_2 thin films before and after durability test by temperature test.

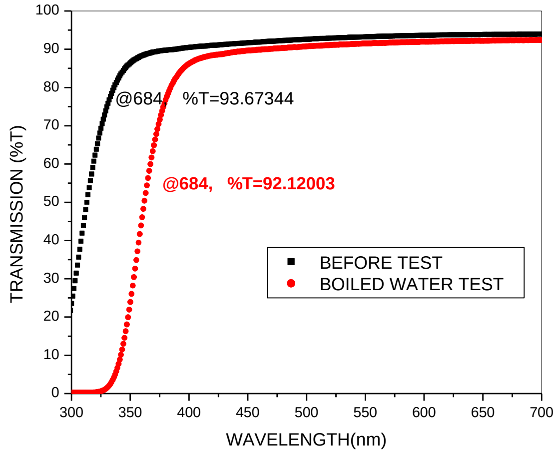
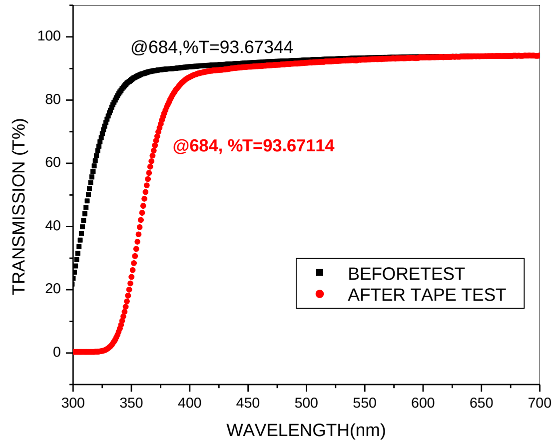
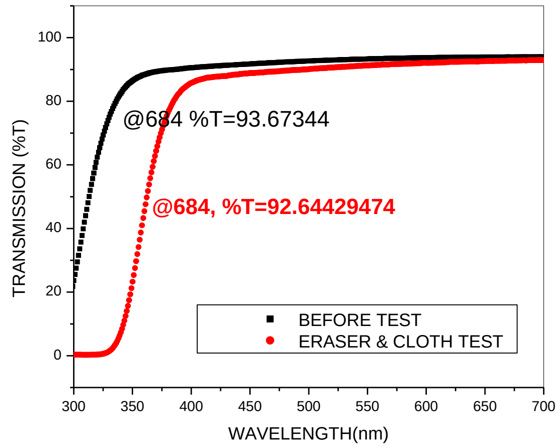


Fig.7 shows the Transmission spectra of MgF_2 thin films before and after durability test by boiled water test.

The effect of rubbing with eraser and cheese cloth with 20 cycles test and the effect of cello tape test on the transmission of MgF_2 thin film is shown in Fig.8 Transmission is found to decrease from 93% to 92% by the eraser and cheese cloth test, and Transmission is found to same for quick removal of cello tape test, it is found to be good adhesion test..



Fig(a)



Fig(b)

Fig.8 (a-b) shows the Transmission spectra of MgF_2 thin films before and after durability test by tape, eraser & cloth test.

The below Fig shows the shows the Transmission spectra of MgF_2 thin films before and after all durability tests. The main observation in this, in case of salt water test Transmission is found to major decrease from 93% to 84%. But in case of cello tape test there is no change in Transmission spectra of MgF_2 thin films before and after test. Total data listed in the below table.

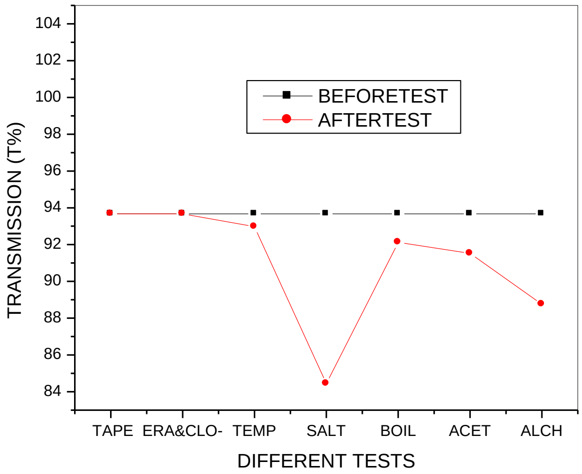


Fig.9 shows the Transmission spectra of MgF_2 thin films before and after all durability tests.

Sl.no	Durability Test	Transmission	
		Before test	**After test**
1	Alchohol,	93.67%	86.76%
2.	Acetone	93.67%	91.67%
3.	Salt water	93.67%	87.48%
4.	Temperature	93.67%	92.96%
5.	Boiled water	93.67%	92.12%
6.	Cello Tape	93.67%	93.67%
7.	Eraser & Cloth	93.67%	92.64%

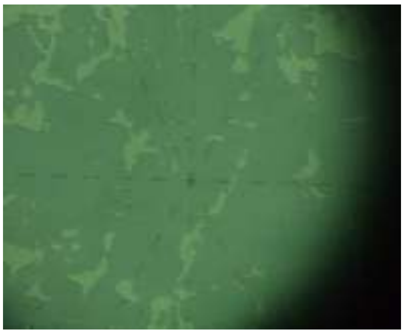


Fig.10

Optical Microscope image of the damage of MgF_2 thin film with the durability test of salt water.

IV. CONCLUSIONS

Structural and optical properties of MgF_2 thin films produced by PVD, technique were studied. The coating of BK7 glass with MgF_2 increased the transmittance and is in good agreement with literature. Durability test was done in different solutions and transmission is found to decrease in all the solutions. But in case of cello tape test there is no change in Transmission spectra of MgF_2 thin films before and after the test.

REFERENCES

[1] H.A. Macleod, Adam Hilger Ltd, London, 2001, p 9, E. D.

[2] H. Hattori, Adv. Mater. 13, 51 (2001)

[3] Y. Zheng, K. Kikuchi, M. Yamasaki, K. Sonoi and K. Uehara, Appl. Opt. 36, 6335 (1997).

[4] L. Schirone, G. Sotgiu and F. P. Califano, Thin Solid Films 297, 296 (1997).

[5] F. Perales, J.M. Herrero, D. Jaque, C. de las Heras, Optical Materials 29 (2007) 783.

[6] H. Yu, H. Qi, Y. Cui, Y. Shen, J. Shao, Z. Fan, Applied Surface Science 253 (2007) 6113.

[7] S. Niisaka, T. Saito, J. Saito, A. Tanaka, A. Matsumoto, M. Otani, R. Biro, C. Ouchi, M. Hasegawa, Y. Suzuki and K. Sone, Appl. Opt. 41, 3242 (2002).

[8] T. Yoshida, K. Nishimoto, K. Sekine and K. Etoh, Appl. Opt. 45, 1375 (2006).