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THE EFFECT OF PROCESS CONDITIONS ON THE PHYSICAL PROPERTIES OF SILVER FILMS PREPARED BY USING SPUTTERING ON POLYESTER SUBSTRATE

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Abstract

Reflective silver films with high quality were prepared on polyester substrate by using sputter depositon techniques. Best reflectivity thin films of silver were produced with process parameters of 10^{-6} Torr as base pressure, 50 W as R.F. power, 5 mTorr as working pressure, and 10 sccm as Ar flow rate. Being deposited with an R.F. power of 50 W, Ag films revealed the highest 96.3 % reflectance as illuminated with a light of 700 nm wavelength.

The adhesion of sample films showed as high as 14 to 20 kg/cm^2, which is suitable for industrial purposes. Their film crystallinity and orientation resulted in the planes of (111) and (200) for the growth with a preferred orientation of <111>, in general. The cross-sections of thin film specimens showed columnar structures. It is noted that columns became coarsened and less dense as R.F. power increased, resulting in a low reflectivity for the product film.

Key words : *silver film, thin reflective film, polyester substrate, sputter deposition*

1. Introduction

To save electrical energy as much as 40 % for fluorescent lighting, the reflectors coated with silver reflective thin films recently became popular with higher reflectivities and long life. The thin films fabricated by using sputtering techniques are produced mainly in U.S.A. On the other hand, some silver films deposited by using evaporation methods show low adhesion in general, although the reflectivity is no problem.

We have studied various PVD methods[1] to obtain thin films with high reflectivity and adhesion on a substrate of polyester[2], for a couple of years. Among these, sputtering is a well known process to produce a high quality thin films[3)-6)]. For this paper in particular, we report the effect of sputtering conditions on the physical properties of resulting films, along with their relations to the microstructural information of each specimen.

2. Sample Preparation and Experimental Setup

As substrate, we have used polyester film with a grade of SH-71 manufactured by SKC[7]. To remove contaminant particles from the substrate surface, ultrasonic cleaning was carried out in diluted acetone and alcohol consecutively, then a blower was used to dry. Reflective thin films were prepared by using R.F. mgnetron sputtering and its deposition source was a silver target with a purity of 99.99%.

For sample depositions, the distance between target and substrate was kept as 50mm and the base pressure was kept down to a range of 10^{-6} Torr. Then pre-sputtering process was carried out to sputter-clean the surface of target for 20minutes. While keeping working pressure and Ar flow rate within ranges of 5 to 30 mTorr and 5 to 30 sccm, respectively. R.F. power was varied within a range of 25 to 100 W.

We measured deposition rate of each thin film as same ways as mentioned in reference 2. The reflectance, adhesion, microstructural orientation, surface morphologies and cross-sections of each specimen were also analyzed as same ways as mentioned earlier[2].

3. Influence of Various Parameters

3. 1 Deposition Rate

Deposition rates increased monotonically as R. F. power values increased in an expected way as shown in Fig. 1, since R.F. power enhances normally the ionization rate and the electrical potential between target and substrate. But the influence of working pressure upon deposition rate

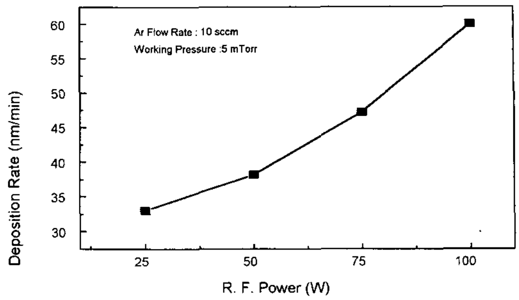


Fig. 1 Deposition rate of magnetron sputtering as a function of R.F. power.

was inversely proportional. This relation is vividly seen in Fig. 2. The deposition rates observed as a function of Ar flow rate reveal a maximum at 10 sccm.

3. 2 Reflectivity

Reflectance of each specimen was obtained by using a SpectroPhotometer with a light source of D65 condition in a wave-length range of 400 to 700nm. Fig. 3 shows the data obtained from the samples prepared to see the difference between the various RF power values. The reflectivity values of Ag films revealed more than 95% as illuminated with a light of 700nm wave-length. Their maximum reflectance showed 96.3% for the films deposited in particular with the process

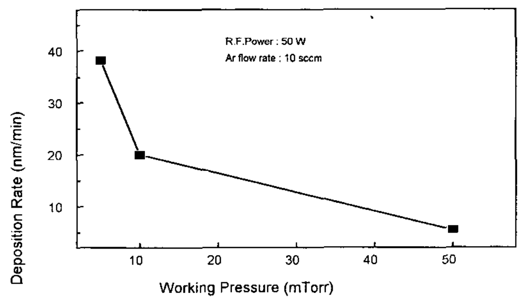


Fig. 2 Deposition rate of R.F. magnetron sputtering as a function of working pressure.

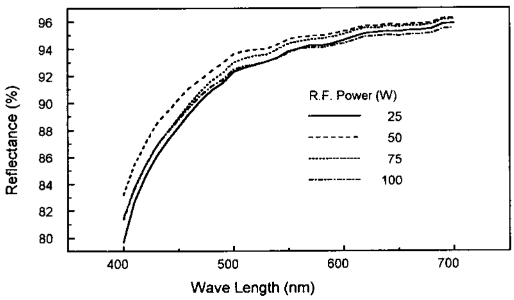


Fig. 3 The effect of R.F. power on the reflectance of Ag film (Ar flow rate : 10 sccm, Working pressure : 5 mTorr).

parameters of 50 W as R.F. power, 5 mTorr as working pressure, and 10 sccm as Ar flow rate.

As working pressure increased during sputtering, the resulting reflectance was monotonically decreased. The relation is well demonstrated with the data shown in Fig. 4. The influence of Ar flow rate was outstanding when RF power of 100 W was applied as seen in Fig. 5, but the case of 50 W showed minimal effect comparingly.

3. 3 Adhesion

Adhesion strength was measured by using a Sebastian pull-tester. The adhesivity of resulted films showed 14 to 20 kg/㎠ monotonaically increasing as the applied R.F. power increased. These values are a lot higher than those of evaporation films[2] and encouraging. The influence of working pressure on adhesivity was inversely proportional as seen in Fig. 6, while that of Ar flow rate was relatively insignificant as seen in Fig. 7.

Film crystallinity and orientation was analyzed by using an XRD. The typical spectrum is shown

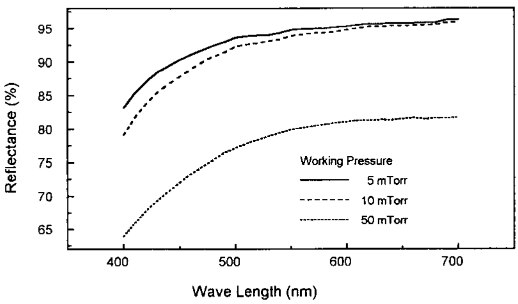


Fig. 4 The effect of main pressure on the reflectance of Ag film (R.F. power : 50 W, Ar flow rate : 10 sccm).

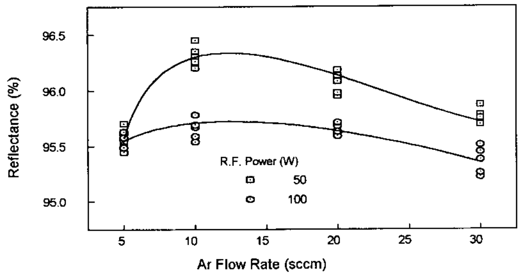


Fig. 5 Reflectance of Ag films deposited with various Ar flow rates (Working pressure : 5 mTorr,.Radiated wave length : 700 nm).

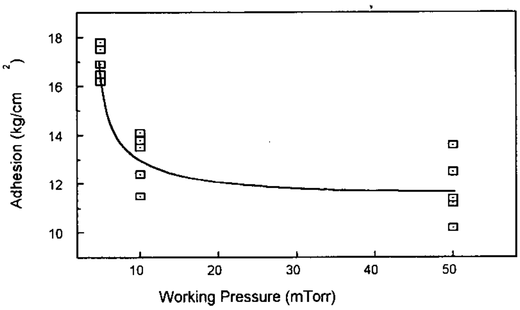


Fig. 6 The effect of main pressure on the adhesion of Ag films (R.F. power : 50 W, Ar flow rate : 10 sccm).

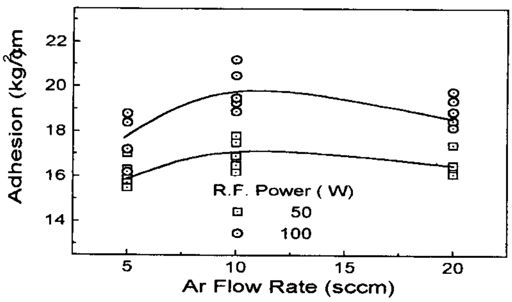


Fig. 7 The effect of Ar flow rate on the adhesion of Ag films, deposited with a working pressure of 5 mTorr.

in Fig. 8. It resulted in the planes of (111) and (200) for the growth with a preferred orientation of <111> instead of a <100> direction, which was the case of evaporation-deposited films[2)]. It is characteristic that the microstucture exhibits a coulumnar structure as seen in Fig. 9, as compared with that of evaporation-deposited films showing a type of condensation[2)]. The columns tend to get thicker as R.F. power increased during sputtering, but seem to be less dense as seen in Fig. 9. It is notable that thinner and denser columns in general result in a higher reflectivity. AFM observations as shown in Fig. 10 are consistant with this.

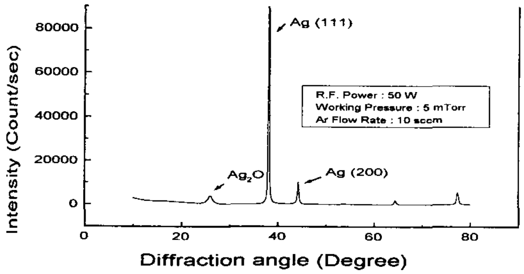
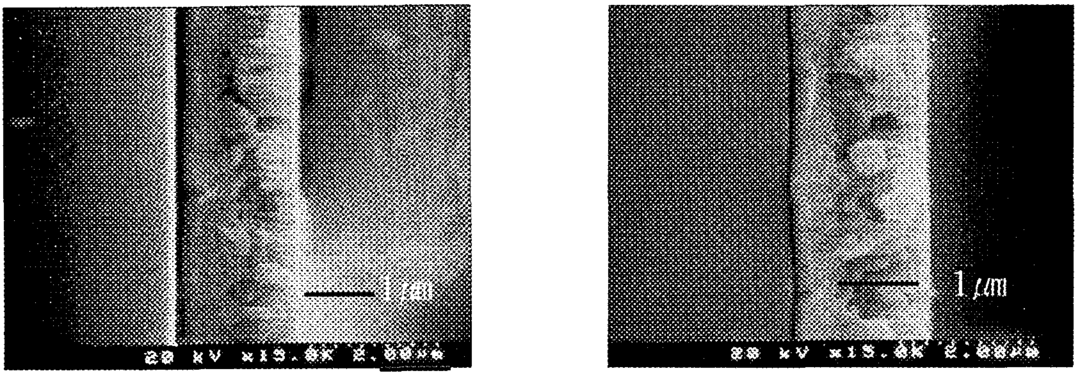
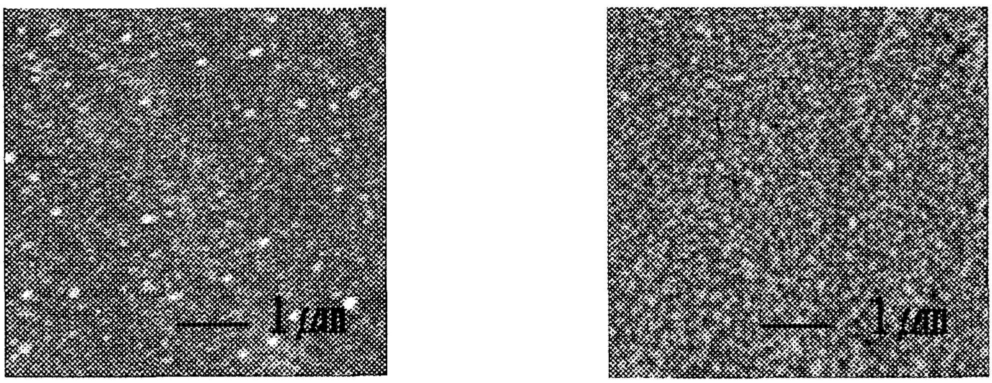


Fig. 8 X-ray diffraction spectrum of Ag film.



(a) (b)

Fig. 9 Typical SEM micrographs of Ag films deposited on glass substrate, (a) R.F. power : 50 W, (b) R.F. power : 100 W (Ar flow rate : 10 sccm, Working pressure : 5 mTorr).



(a) (b)

Fig. 10 Typical AFM Surface morphologies of Ag films deposited on polyester film substrate, with (a) R.F. power : 50 W, and (b) R.F. power : 100 W (Ar flow rate : 10 sccm, Working pressure : 5 mTorr).

4. Concusions

Best reflectivity thin films of silver were produced with process parameters of 10^{-6} Torr as base pressure, 50 W as R.F. power, 5 mTorr as working pressure, and 10 sccm as Ar flow rate. Being deposited with an R.F. power of 50 W, Ag films revealed the highest 96.3 % reflectance as illuminated with a light of 700 nm wave-length, while the others deposited with different R.F. power values showed more than 95% for their reflectivity.

Meanwhile, the adhesion of sample films showed as high as 14 to 20 kg/㎠, which is suitable for industrial purposes. Their film crystallinity and orientation resulted in the planes of (111) and (200) for the growth with a preferred orientation of <111>, in general. The cross-sections of thin film specimens showed columnar structures. It is noted that columns became coarsened and less dense as R.F. power increased, resulting in a low reflectivity for the product film.

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