Effects of surface geometry of MgO protective layer for AC-PDPs

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Abstract

MgO thin films were deposited by e-beam evaporator using the 2-step method for alternate current plasma display panels (AC-PDPs). Glancing angle deposition (GLAD) method was employed to produce various surface geometry of the thin film; the bottom layer was deposited on a substrate by normal e-beam evaporation method and the top layer was deposited on bottom layer with 85° by GLAD method. Results show that firing and sustain voltages improved as the sharpness of surface and isolated columnar structures increases, respectively.

1. Introduction

The MgO thin film has been used for AC-PDPs for decades because of its excellent erosion resistant to plasma ions (Ne^+) and discharge characters [1-2]. Particularly, the discharge character of MgO strongly depends on the microstructures of MgO film, such as grain size, texture, residual stress and surface morphology [3-4]. Although the effect of grain size, texture and residual stress on the discharge has been investigated, the effect of surface morphology on the discharge character is not well established due to the lack of systematic study. Thus, the present study is to report the effect of surface geometry on the properties of MgO thin film. In particular, main focuses are on; i) modifying the surface roughness and the porosity of thin film by varying film thickness, and ii) the corresponding discharge character of thin film.

2. Experimental

Two layers of MgO film were deposited; the first layer was deposited on the substrate by a normal e-beam evaporation method, and then the second layer was deposited on the first layer using the GLAD method with 85° flux angle, as shown in Fig. 1. GLAD method was employed to modify the surface morphology with varying thickness of the second layer on the first layer of the film [5-7]. This 2-step deposition method can effectively produce a various roughness and porosity of MgO thin films with exhibiting isolated columnar structure (insets in Figs. 2e-h).

To examine the basic properties of the film, 100nm-thick thermal-oxidized SiO_2/Si wafers were used as substrate, and the 2” test glass panels were used to measure the discharge characteristics. The base pressure of the chamber was maintained at approximately 5×10^{-4} Pa and acceleration voltage was 10.02 kV. For all samples, deposition rate of the first and the second layer were 0.3 and 0.1 nm/sec, respectively. Final thickness of first layer was about 600 nm and that of second layer was approximately 10, 50, and 100 nm. The flux angle (α) for the first and second layer was normal (0°) and 85°, respectively.

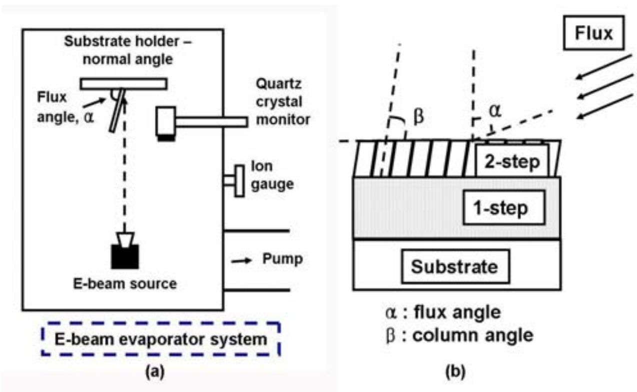

Fig. 1. Schematics of e-beam evaporator system and the GLAD process (a), and deposition flux (α) angle and column angle (β) depicted in (b).

Film density was calculated by gravimetric measurement [8]. The surface morphology of the MgO film was characterized by Scanning Electron Microscope (SEM), and Atomic Force Microscopy (AFM). In addition, the discharge characteristics were measured using the unsealed 2" test panel in the chamber filled with Ne-4%Xe gas at 4.0x10^4 Pa.

3. Results and discussion

Figure 2 shows SEM micrographs of MgO films deposited by e-beam evaporator using 2-step method, as described in experimental procedures. As the thickness of the second layer was increased, the roughness of surface and the porosity of the thin film increased (Fig. 2 and Fig. 3). Moreover, the isolated columnar structure was distinguished and inclined about 25° from the substrate surface normal (Figs. 2e-h). In case of 10nm-thick second layer, the morphology of surface was similar to that of MgO film deposited by normal method (Figs. 2a-d); however, its roughness was slightly increased (Fig. 3). In case of 50nm and 100nm-second layer, roughness was lower than the height of columnar, since the columns on second layer were inclined.

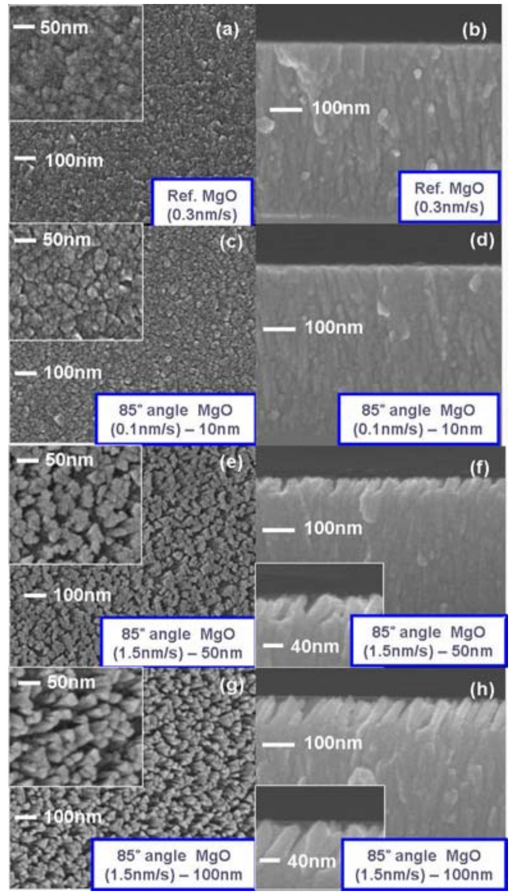

Fig. 2. SEM micrographs show the surface and the cross-section of the MgO films deposited by 2-step deposition method; the thickness of the second layer (a), (b) 0nm: reference MgO, (c), (d) 10nm, and (e), (f) 50nm, (g), (h) 100nm. 85° is angle between the flux and the normal direction of the substrate.

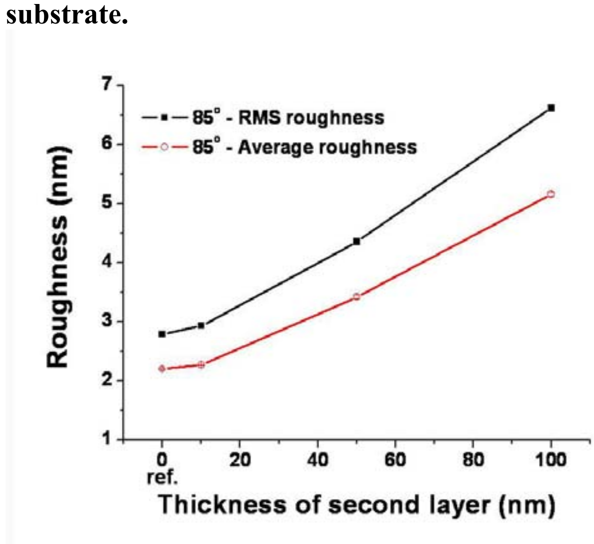

Fig. 3. Roughness plot shows that RMS and average roughness depends on the thickness of second layer.

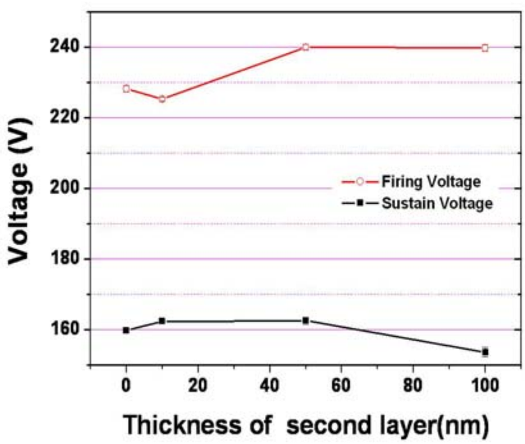

Fig. 4. Discharge characteristics plot shows that both firing and sustain voltage depend on the thickness of second layer. As the thickness of the second layer changes, the surface morphology also alters. Uncertainty of this plot is the same size as the symbols.

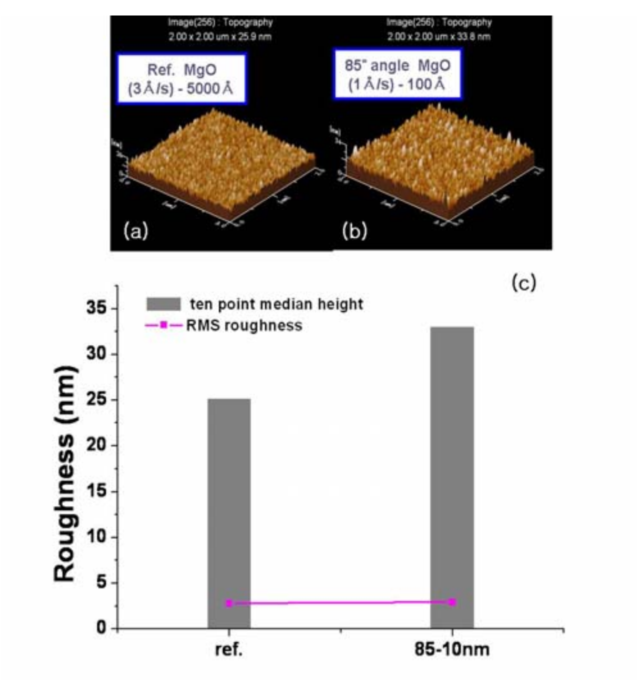

Fig. 5. Topographies of the MgO films deposited by 2-step deposition method; the thickness of the second layer (a) 0nm: reference MgO, and (b) 10nm. 85° is angle between the flux and the normal direction of the substrate. (c) shows the roughness of film (a), and (b).

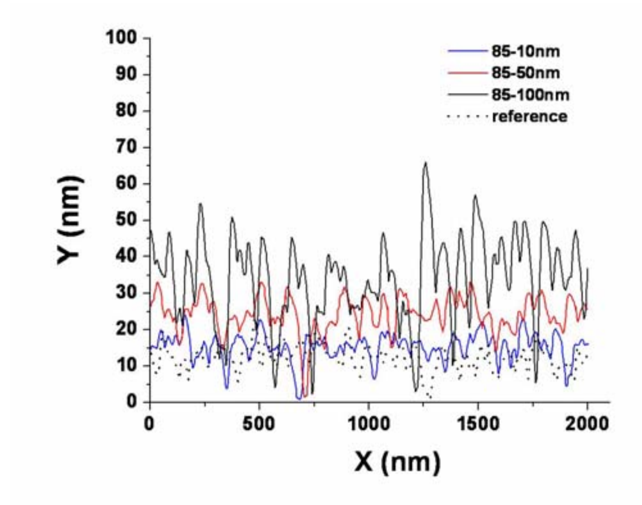

Fig. 6. Configuration of MgO film surface deposited by 2-step method with various second layer; 0 ~ 100 nm.

The measured discharge voltages exhibited two different trends as shown in Fig. 4. Firstly, firing voltage increased and then saturated as the second layer thickness was increased from 10 to100 nm (Fig. 4). This observation was somewhat expected since the firing voltage increased with decreasing the density of MgO film [8-9]. One interesting observation here is that firing voltage for 10 nm thickness was lower than that of the reference, although the density and the RMS roughness of 10nm-second layer were nearly the same as those of the reference. This interesting observation may be explained by the difference in feature sharpness on the second layer, which can be estimated by topographies and ten-point median height (Fig. 5). The results showed that 10nm-second layer case exhibited sharper tip (Fig. 5) as compared to the reference case. Hence, we propose that the presence of sharp tip on the surface may decrease the firing voltage. In case of 50 and 100nm-second layer, the density of film was significantly lower than that of reference. Expectedly, firing voltage increased, but with sharp tip on the surface. Thus, to improve (lower) firing voltage, both the surface geometry and density of MgO film must be considered.

Secondly, sustain voltage was nearly constant up to thickness of 50nm. However, sustain voltage for 100nm-second layer film appreciably dropped as compared to other films. This may be attributed to a large surface area as shown in Figs. 2(g) & (h), and 6. As the second layer of thickness increased, the effective surface area increased due to the increase in distance between separated columns (Figs. 2(g) & (h), and 6). Generally, sustain voltage is related to the wall charge, which is generated by accumulation of electrons or ions attracted by electric field on the surface [10]. Due to such wall charge, discharge sustained under lower voltage than firing voltage. Hence, we expect that higher wall charge may occur with a larger effective surface area, and subsequently higher wall charge would decrease the sustain voltage. Therefore, it is reasonable to postulate that larger effective surface area would result in lower sustain voltage.

4. Summary

Present study shows that GLAD method can produce more porous and rougher MgO thin film than normal method can yield. In addition, the corresponding characteristics of discharge voltages exhibited two trend; i) firing voltage was improved when MgO film exhibited sharp tips on the surface and high density, and ii) sustain voltage was improved, when columnar structure were sparsely separated to each other; that says, sustain voltage was low, when the effective surface area of film was large. Therefore, the present study clearly shows that the film surface morphology and density of the thin film must be considered to improve an overall discharge character.

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6. References

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