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Discharge and structural characteristics of MgO thin films under various O_2 and H_2 gas flow rates during MgO deposition when using ion plating method in microdischarge cells

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ABSTRACT

This paper has investigated the characteristics of structure and discharge for the MgO thin films grown by the ion plating process by varying the oxygen (O_2) and hydrogen (H_2) flow rates. The structural characteristics of the MgO film are measured by scanning electron microscopy (SEM), X-ray diffraction (XRD), and atomic force microscopy (AFM). The discharge characteristics are examined based on the firing voltage, secondary electron emission, sustain delay, and address delay. By increasing the O_2 flow rates during ion plating process, the grain sizes of the MgO thin films are decreased and the firing voltages are decreased, which would be due to the improvement of secondary electron emission characteristics. In addition, as the O_2 gas flow rates are increased in the range from 200 to 260 sccm, the sustain delay times are reduced, on the contrary, the address delay times are increased. Whereas, by increasing the H_2 flow rates, the grain sizes of the MgO thin films are increased. In particular, the lower firing voltages are measured at a H_2 flow rate of 40 sccm, which also would be due to an enhancement of secondary electron emission characteristics. When H_2 flow rates are increased from 0 to 40 sccm, the address delay times are greatly reduced. Whereas, when H_2 flow rates are beyond 40 sccm, the address delay times are slightly increased. However, the sustain delay times are slightly increased as the H_2 flow rates are increased from 0 to 60 sccm. Accordingly, the optimal control of both O_2 and H2 flow rates during the MgO film deposition using ion plating method can contribute to enhancing the discharge characteristics in ac plasma display panels (ac-PDPs).

KEYWORDS

MgO protective layer; delay time; firing voltage; secondary electron emission; ion plating; oxygen (O_2) and hydrogen (H_2) flow rates

1. Introduction

The MgO films are widely used as a protective layer for plasma display panel (PDP) due to having the high durability, low sputtering erosion, and high secondary electron emission coefficient [1–12]. Among the various methods to deposit the MgO protective layer, the electron beam evaporation is well known and used to be industrial fabrication method. The

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characteristics of the protective layer such as MgO film can affect the life time and discharge characteristics of alternating-current (ac) PDP by protecting cells against ion bombardment during the discharge [1, 2, 5, 7, 10, 12]. Many researchers have studied on the discharge characteristics of small size test panel with protective layer such as MgO thin films deposited by electron beam evaporation method with respect to oxygen (O_2) and hydrogen (H_2) flow rates [2, 3, 9-12]. The secondary electron emission affecting the discharge characteristics of MgO films largely depends on the film properties such as crystal orientation, stoichiometry, film density, surface morphology, and roughness [1, 5, 7, 10, 13]. Namely, the secondary electron emission of MgO films is one of the most important factors for determining the discharge voltage and discharge response time. However, the relations of MgO films with respect to O_2/H_2 flow rates and various discharge characteristics such as firing voltage, secondary electron emission, sustain discharge delay, and address discharge delay in a commercial 42-in. ac-PDP module have not yet been studied systematically in the case of using ion plating method [14].

Accordingly, this paper examines the detailed sustain and address discharge delay and structural characteristics of MgO thin films deposited by the ion plating method relative to the O_2 and H_2 flow rates. The employed test panel is a commercial 42-in. ac-PDP module with a He (35%)-Xe (11%)-Ne gas compositions and close-type barrier.

2. Experiment set-up

Figure 1 (a) shows the schematic diagram of ion plating method for growing the MgO thin films employed in this research. The MgO thin films were deposited on the glass and the dielectric layer of ac-PDP by using ion plating system. The MgO thin films were prepared by the MgO pellet (99.99%) as an evaporation source with respect to oxygen (O_2) and hydrogen (H_2) flow rates. The O_2 and H_2 flow rates were varied from 200 to 260 sccm and from 0 to 60 sccm, respectively. The base pressure of the vacuum chamber was maintained at 2.0×10^{-6} Torr before deposition. The Ar gas was fed into the deposition chamber to maintain the process pressure at 1.0×10^{-3} Torr. The RF (13.56 MHz) generator was used as a bias power for maintaining the substrate holder to be negative. Figure 2 (b) shows the single pixel structure of the test panel employed in this research, where the X is the sustain electrode, the Y is the scan electrode, and the A is the address electrode. The detailed panel specifications are listed in Table 1. A commercial 42 in ac-PDP module with a working gas pressure of 420 torr was employed in this study, and its structure and dimensions were an XGA grade PDP with a box-type barrier rib. The ITO width and gap were 360 and 85 μm, respectively. Bus electrode width was 60 μm and He (35%)-Xe (11%)-Ne gas compositions were used for gas discharge. The secondary electron emission coefficient of MgO layer was measured using the γ-focused ion beam system [15]. X-ray diffraction (XRD, Phillips PW3710) and field emission scanning electron microscopy (FE-SEM, HITACHI SU8220) were used to estimate the dependence of the film crystallinity and analyze the surface morphology with O_2 and H_2 flow rates, respectively. Furthermore, the roughness of the MgO film was analyzed by atomic force microscopy (AFM). The sustain frequency and the duty ratio of the sustain pulses for the sustain period were 20 kHz and 30%, respectively.

3. Results and discussion

3.1. Experimental observation of structural characteristics of MgO thin film of 42-in. PDP cell under various oxygen and hydrogen flow rates

Figure 2 shows the surface morphologies of MgO thin films as a function of O_2 and H_2 gas flow rates in the 42-in. test panel, respectively. As the O_2 gas flow rates were increased in the

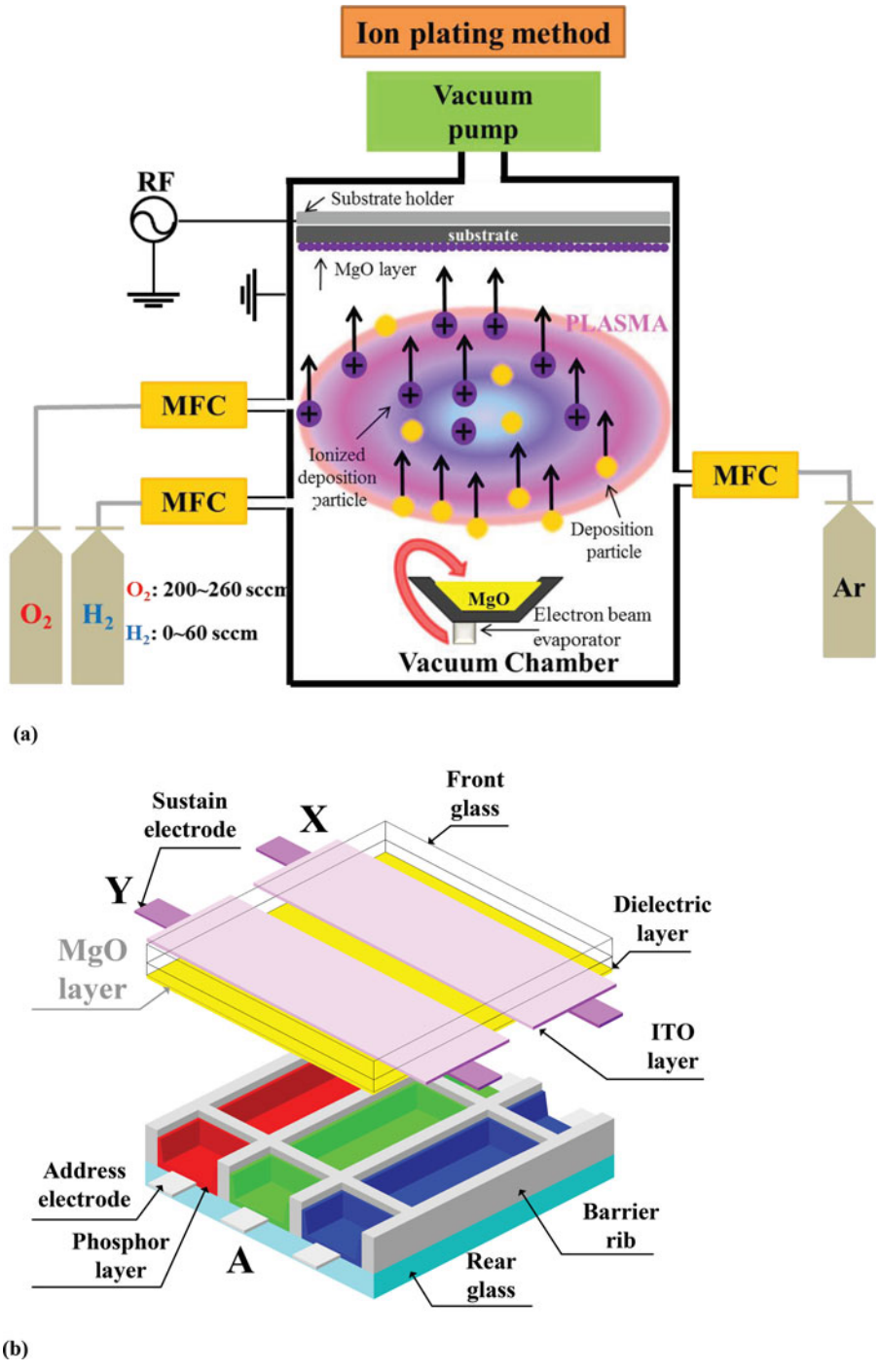

Figure 1. (a) Schematic diagram of ion plating method for growing the MgO thin films and (b) the single pixel structure of the test panel.

range from 200 to 260 sccm, the grain sizes of the MgO surface were observed to be decreased and dense, as shown in Fig. 2 (a). In contrast, when the H_2 gas flow rates were increased in the range from 0 to 60 sccm at a constant O_2 flow rate of 220 sccm, the grain sizes were observed to be increased, as shown in Fig. 2(b).

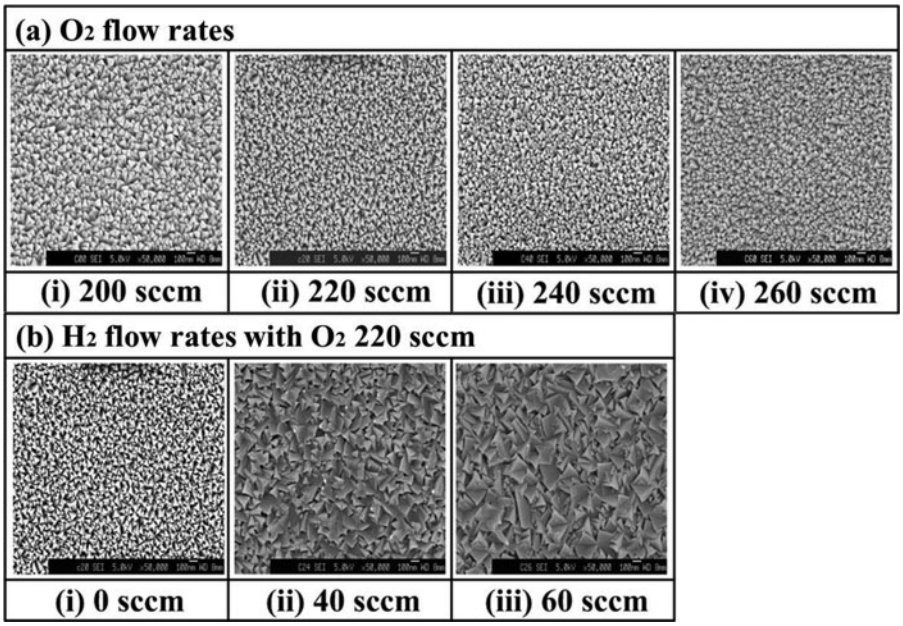

Figure 2. Comparison of SEM images of MgO thin films under various (a) O_2 and (b) H_2 flow rates, respectively.

Figure 3 shows the surface roughness of MgO thin films measured by the AFM analysis as a function of O_2 and H_2 gas flow rates in the 42-in. test panel, respectively. The roughness of MgO films was changed depending on the O_2 and H_2 gas flow rates. As shown in Fig. 3, as the O_2 gas flow rates were increased in the range from 200 to 260 sccm, the roughness of the MgO surface was decreased. That is, the roughness of MgO film grown under high O_2 flow rate condition was observed to be uniform. Whereas, as the H_2 gas flow rates were increased in the range from 0 to 60 sccm, the roughness of the MgO surface was more increased. This experimental result illustrates the O_2 and H_2 gas flow rates would play a different role in growing the MgO layer, especially the surface morphology of the MgO.

Figure 4 shows the X-ray diffraction (XRD) spectra of the MgO thin films for checking the effects of O_2 and H_2 gas flow rates on the crystallinity of the MgO films in the 42-in. test panel by using the X-ray diffractometer. In Fig. 4 (a), as the O_2 flow rates were increased in the range from 200 to 220 sccm, the intensities of (111) and (222) peaks were increased, which implied that the crystallinity of the MgO films were improved thanks to the increase in the O_2 flow rates. However, the result of Fig. 4 (a) also showed that the intensities of (111) and (222) peaks were saturated for the O_2 flow rates greater than 220 sccm. On the other hands, as shown in Fig. 4 (b), when the H_2 flow rates were increased in the range from 0 to 60 sccm,

Table 1. Specifications of 42-in. AC-PDP panel cells structure used in this study.

Panel	
ITO	
width	360μm
gap	80μm
Bus width	60μm
Pixel Pitch	912μm x 693μm
Gas chemistry	He (35%)-Xe (11%)-Ne gas
Barrier rib type	Closed rib

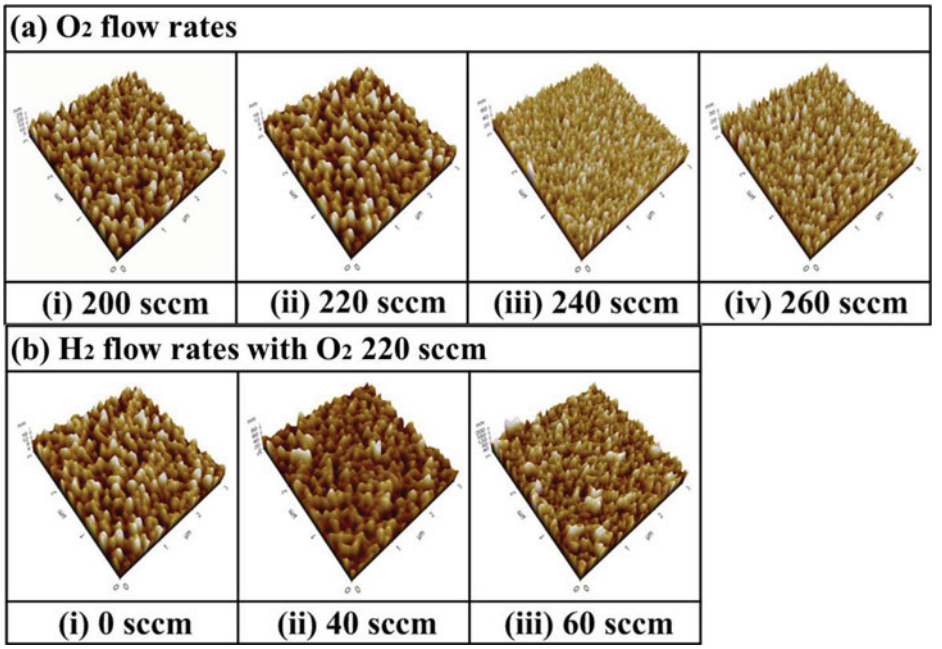

Figure 3. Comparison of AFM images of MgO thin films under various (a) O_2 and (b) H_2 flow rates, respectively.

the intensities of (111) and (222) peaks were decreased, which would be due to the reduction of crystallinity of the MgO films.

3.2. Experimental results of address and sustain discharge characteristics of 42-in. PDP cell adopting MgO films grown under various oxygen and hydrogen flow rates

Figure 5 (a) shows the relations between the secondary electron emission and the X-Y firing voltage with respect to the O_2 flow rates in the 42-in. test panel. As shown in the γ process data of the top of Fig. 5 (a), the secondary electron emissions (γ process) for the MgO layer were increased with an increase in the O_2 flow rates from 200 to 240 sccm. This improvement of the secondary electron emission characteristics of the MgO films would be mainly due to

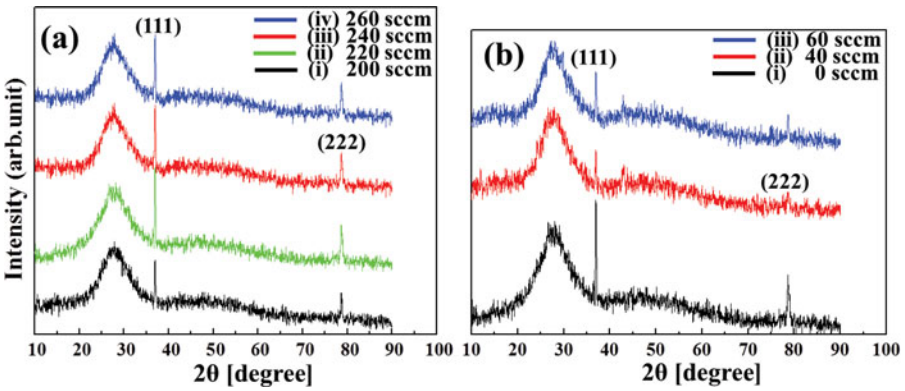

Figure 4. Comparison of XRD patterns of MgO thin films under various (a) O_2 and (b) H_2 flow rates, respectively.

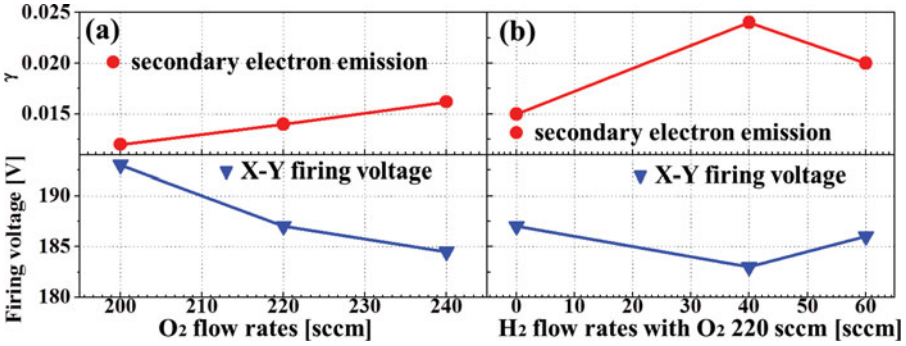

Figure 5. Relations between secondary electron emission (top part) and X-Y firing voltage (bottom part) with (a) O_2 and (b) H_2 flow rates, respectively.

the improvement of crystal orientation and surface properties of the MgO thin films grown under the O_2 rich growth condition during the ion plating deposition process, which was confirmed by the SEM, AFM, and XRD data. As shown in the bottom of Fig. 5 (a), as the O_2 flow rates were increased from 200 to 240 sccm, the firing voltages were decreased, thanks to the enhancement of secondary electron emissions.

Figure 5 (b) shows the relations between the secondary electron emission and the X-Y firing voltage with respect to the H_2 flow rates at a constant of O_2 flow rate (= 220 sccm) in the 42-in. test panel. As shown in the γ process data of the top of Fig. 5 (b), the secondary electron emission for the MgO layer were remarkably increased with an increase in the H_2 flow rates from 0 to 40 sccm. The corresponding X-Y firing voltage showed the lowest value at the H_2 flow rate of 40 sccm thanks to the better secondary electron characteristics, as shown in the bottom of Fig. 5 (b).

Figure 6 shows the changes in the sustain delay and address delay characteristics as a function of O_2 and H_2 gas flow rates in the 42-in. test panel, respectively. As shown in Fig. 6 (a), as the O_2 gas flow rates were increased in the range from 200 to 260 sccm, the sustain delay times were reduced, on the contrary, the address delay times were increased. Whereas, as shown in Fig. 6 (b), when H_2 flow rates were increased from 0 to 40 sccm, the address delay time was greatly reduced. Whereas, when H_2 flow rates were beyond 40 sccm, the address delay time was slightly increased. However, the sustain delay times were slightly increased as the H_2 flow

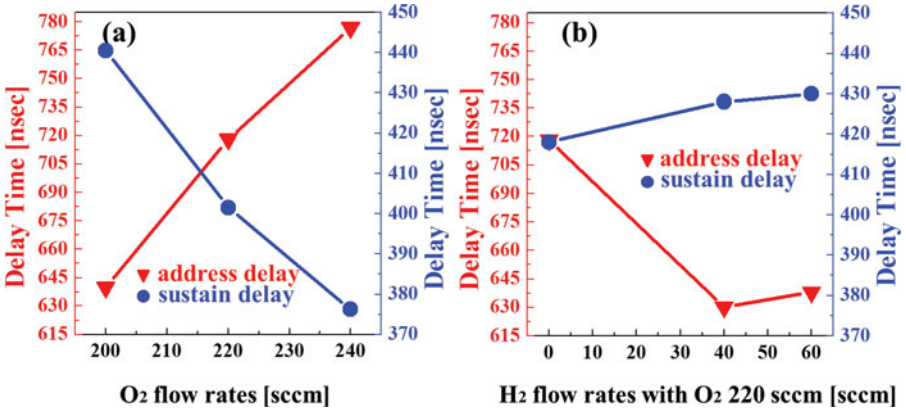

Figure 6. Comparison of statistical address discharge delay times and sustain discharge delay times under various (a) O_2 and (b) H_2 flow rates, respectively.

rates were increased from 0 to 60 sccm. Therefore, considering both the sustain and address delay times for producing the stable discharge, the optimal growth condition of the MgO films should be determined. The experimental results on the O_2 and H_2 flow rates during the ion plating growth process, it confirms that it is very important to optimize the O_2 and H_2 flow rates during the ion plating growth process for obtaining the high quality MgO layer suitable for a high speed and low driving voltage.

4. Conclusions

In summary, we have studied the effects of the oxygen (O_2) and hydrogen (H_2) flow rates during the MgO film deposition using ion plating method on the discharge and structural characteristics of MgO thin films, which affect the firing voltage, secondary electron emission, delay times in the micro-discharge cells with the 42-in. ac-PDPs. The properties of MgO films were improved when the high O_2 flow rates and H_2 flow rates at 40 sccm during the film deposition. Therefore, the secondary electron emission of MgO thin films were enhanced, thereby reducing the X-Y firing voltages. Accordingly, the high O_2 flow rates with H_2 flow rates at 40 sccm during the MgO film deposition using ion plating method can contribute to enhancing the discharge characteristics in ac plasma display panels (ac-PDPs).

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