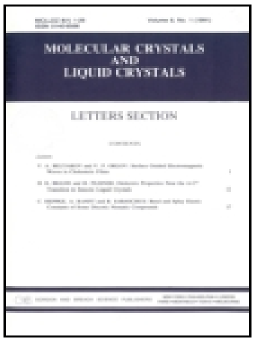

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Effects of RF-Plasma Pretreatment on Panel-Aging Characteristics in AC Plasma Display Panel with Full-HD Cell Size

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The organic impurities, such as C_xH_y, on the MgO surface are known to be an important parameter that affects the panel-aging characteristics in an ac plasma display panel (PDP). Accordingly, the RF-plasma pretreatment on the MgO layer is adopted to reduce the panel-aging process time by reducing the organic impurities. The resultant changes in the discharge characteristics during the panel-aging process, including the firing voltage, formative address delay time, statistical address delay time, and wall voltage variation, were examined in comparison with both cases with and without plasma pretreatment on MgO layer using various gases in the 50-in. full-high definition ac-PDP with He (35%) - Xe (11%) contents. It is concluded that the Ar or Ar followed by O_2 plasma pretreatment was the most effective in eliminating the residual impurities on the MgO surface, thereby reducing the panel-aging process time.

Keywords 50-in. full-HD AC-PDP panel; plasma pretreatment; MgO; TOF-SIMS; organic matter; impurity; AFM; firing voltage; formative address delay time; statistical address delay time; wall voltage variation; V_t closed curve

1. Introduction

The MgO layer is used as a protective layer in ac-PDPs due to its strong resistance to ion sputtering as well as high secondary electron emission coefficient [1–3]. Recently, to lower the panel fabrication cost, the PDP industry is focused on reducing the panel-aging process time in plasma displays, particularly for full-high definition (FHD) PDPs with very small discharge cells. The initial surface state of the MgO thin film prepared by the ion-plating method is very non-uniform and has many impurities on the MgO surface [4, 5]. Accordingly, the panel-aging process is necessary to obtain the uniform MgO surface condition and to reduce the impurities, such as C_xH_y, on the MgO surface for the stable discharge [6]. As such, the surface state of the MgO surface in the front panel after the panel-aging process is important for producing stable reset and address discharges in plasma display panel (PDP) cells, as the discharge characteristics can vary depending on the state of the MgO surface. Moreover, our previous experiments showed that the variations

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in the surface state of the MgO layer, especially organic impurities, with respect to the ion bombardments during the panel-aging process were very important for determining the formative and statistical address delay times (T_f and T_s) and wall charge retention capability (wall voltage variation, ΔVw) [7]. These parameters are significant factors for determining a stable driving margin for a PDP. In particular, the wall charge retention capability that can constantly maintain wall charges from the first to the last scan line is very critical for a stable driving margin in a PDP [8].

Accordingly, in this paper, the RF-plasma pretreatment on the MgO layer under various plasma gas compositions is adopted to reduce the panel-aging process time. In particular, the RF-plasma pretreatment used the three kinds of plasma gas compositions such as O_2 followed by Ar, Ar, and Ar followed by O_2, in order to investigate which gas in RF-plasma pretreatment can contribute to reducing the panel-aging process time for better discharge characteristics of ac-PDPs. The resultant changes in the MgO and discharge characteristics during the panel-aging process, such as organic impurity, roughness, firing voltage, formative address delay time, statistical address delay time, and wall voltage variation, were examined in comparison with the panel without the plasma pretreatment on MgO layer in the 50-in. FHD ac-PDP with He (35%) - Xe (11%) contents.

2. Experimental Setup

Figure 1 shows a schematic diagram of the RF-plasma equipment used for the plasma pretreatment system. The RF (13.56 MHz) input power and the process time for plasma pretreatment were 4 kW and 30 minutes, respectively [9]. The panel without plasma pretreatment was used as the reference panel. The RF-plasma pretreatment used the various plasma gas compositions, such as O_2 followed by Ar [i.e., gas mixture: O_2>Ar (O_2, 201 sccm (main gas) and Ar, 22 sccm (additional gas))], only Ar (240 sccm), and Ar followed by O_2 [i.e., gas mixture: Ar > O_2 (Ar, 189 sccm (main gas) and O_2, 21 sccm (additional gas))].

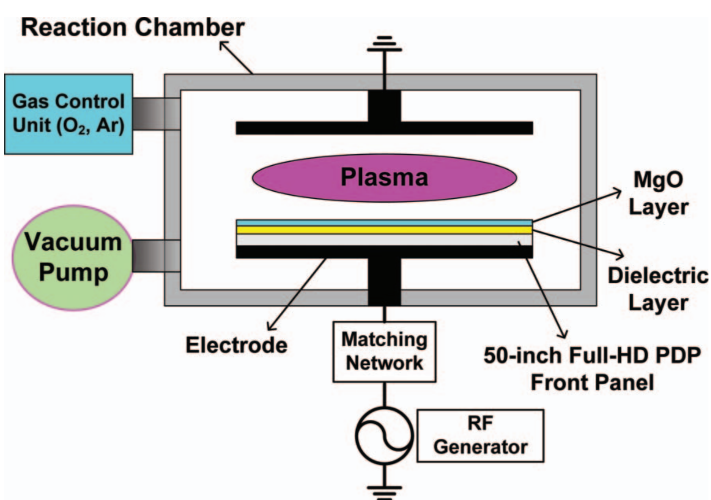

Figure 1. Schematic diagram of RF plasma equipment used for plasma pretreatment system.

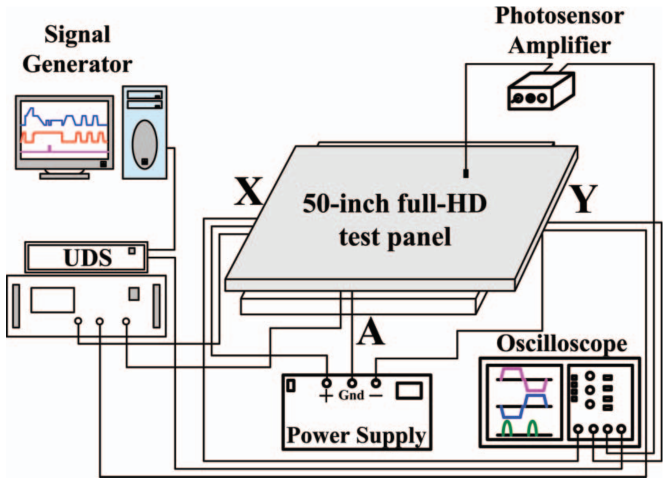

Figure 2. Schematic diagram of experimental setup employed in this research.

Figure 2 shows the optical-measurement systems and 50-in. FHD test panel with three electrodes used in this experiments, where X is the sustain-, Y the scan-, and A the address-electrode. A signal generator and photo-sensor amplifier (Hamamatsu, C6386) were used to measure the IR emission and V_t closed curve, respectively.

Figure 3 shows a schematic diagram of a single pixel from the 50-in. FHD AC-PDP panel employed in this experiment. The gas composition was Ne-Xe (11%)-He (35%) under a pressure of 430 Torr. Table 1 lists the detailed specifications for the various test panels, which were exactly the same, except for the plasma pretreatment gas composition.

Figure 4 shows the applied sustain driving waveform for the panel-aging process used in this study. The duty ratio and frequency for the sustain period were 40% and 25 kHz,

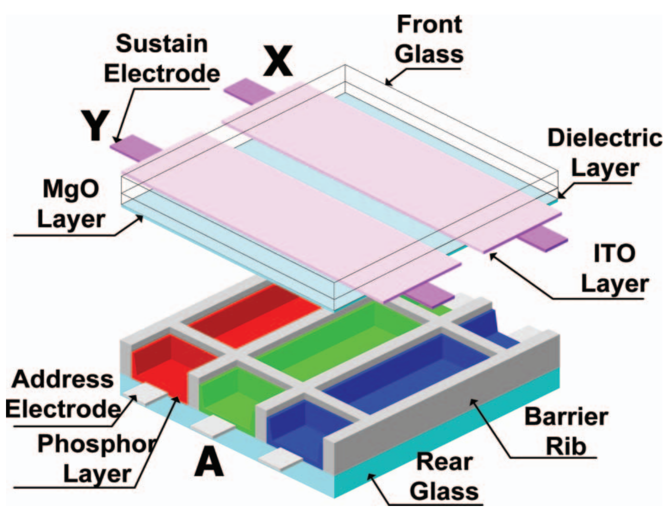

Figure 3. Schematic diagram of single pixel structure in 50-inch FHD AC-PDP.

Table 1. Specifications of 50-inch FHD AC-PDP used in this study

Front Panel		Rear Panel	
ITO width	210 μm	Barrier rib width	50 μm
ITO gap	70 μm	Barrier rib height	120 μm
Bus width	70 μm	Address width	85 μm
Cell pitch		192 μm × 576 μm	
Gas chemistry		Ne-Xe (11%)-He (35%)	
Gas pressure		430 Torr	
Barrier rib type		Closed rib	

respectively. The panel-aging process time was 6 hours. The same sustain voltages with the amplitude of 150 and -150 V were applied to the test panels during the aging process.

3. Results and Discussion

3.1 Change in Surface Characteristics of MgO Layer with and without RF-Plasma Pretreatment on MgO Layer

Figure 5 shows the changes in the organic matters on the MgO surfaces in the 50-in. test panels with the MgO layers prepared by the RF-plasma pretreatment under various plasma gas compositions. The organic impurities on the MgO surface were measured by using the time of flight secondary ion mass spectrometry (TOF-SIMS) analysis. The TOF-SIMS measured the total count of the secondary ions emitted from the MgO surface when the MgO surface was struck only for 100 sec by the primary Bi ions from the ion gun with 25 keV. The primary ion beam energy was 1 pA, the measurement area was 150 × 150 μm^2, and the measurement depth was about 10 nm. The electron gun was used not to charge the dielectric MgO surface by the secondary ion when it was sputtered during measurement. As shown in Figure 5, in the case of O_2>Ar plasma pretreatment, the organic matter on the MgO layer was almost the same in comparison with the reference panel. However, in the both cases of Ar and Ar>O_2 plasma pretreatments, the each organic matter on the MgO

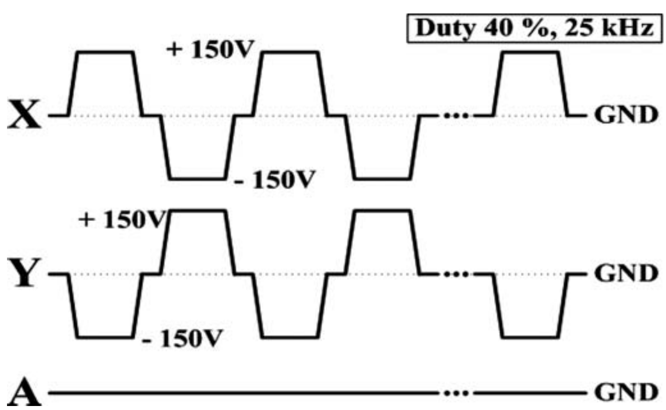

Figure 4. Schematic diagram of sustain driving waveform for panel-aging process used in this study.

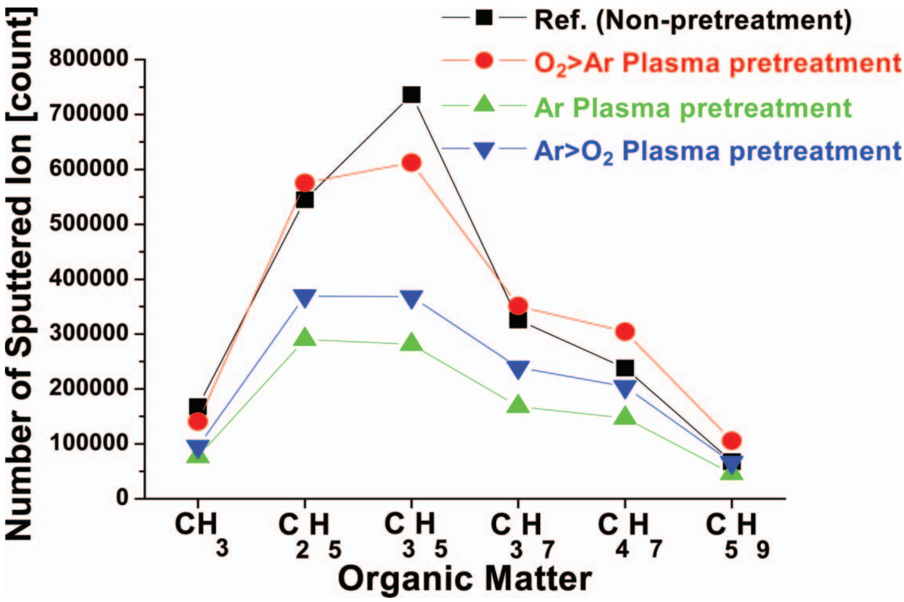

Figure 5. Comparison of organic matter (C_xH_y) on MgO surface based on TOF-SIMS analysis of 50-inch FHD panels prepared using RF-plasma pretreatment on MgO layer under various plasma gases, O_2 > Ar, Ar, and Ar > O_2.

layer was remarkably reduced in comparison with the reference panel. Accordingly, it was confirmed from the results of Figure 5 that the physical sputtering such as the Ar RF-plasma pretreatment was more effective in reducing the organic matters on the MgO surface than the chemical sputtering such as the O_2 RF-plasma [4].

Figure 6 shows the changes in the two-, three-dimensional AFM images of the MgO surface in the 50-in. test panels with the MgO layer prepared by the RF-plasma pretreatment under various plasma gas compositions. The detailed roughness data obtained from the AFM images of Figure 6 are given in Table 2. As shown in Figure 6, in the case of O_2 > Ar plasma pretreatment, the surface morphology of the MgO layer was almost the same as that of

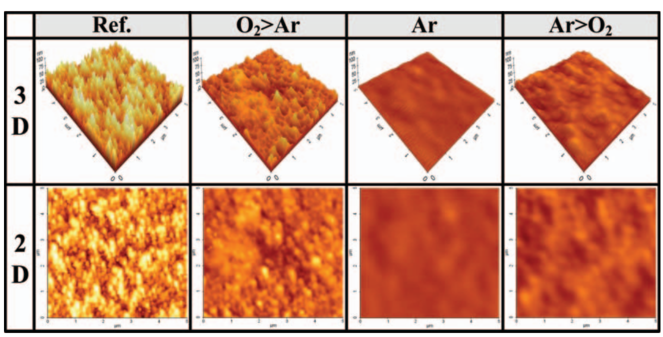

Figure 6. Comparison of two- and three-dimensional (2-D and 3-D) AFM images of MgO surface measured from 50-inch FHD panels prepared using RF-plasma pretreatment on MgO layer under various plasma gases, O_2 > Ar, Ar, and Ar > O_2.

Table 2. Comparison of roughness of MgO surface measured from 50-inch FHD panels prepared by using RF-plasma pretreatment on MgO layer under various plasma gases

	Roughness [Rrms, Å]
Ref. (non-plasma pretreatment)	139.1
O_2 > Ar Plasma pretreatment	80.1
Ar Plasma pretreatment	20.7
Ar > O_2 Plasma pretreatment	50.2

the MgO layer without the plasma pretreatment (Ref. panel). However, in the both cases of Ar and Ar>O_2 plasma pretreatments, the surface morphologies of the MgO layer were remarkably changed to be smooth. The pyramidal morphologies of MgO surfaces were eliminated in both cases of Ar and Ar>O_2 plasma pretreatments, as shown by the AFM images in Figure 6. This elimination was mainly due to the physical sputtering caused by the ion bombardment during the Ar or Ar>O_2 plasma pretreatments. As shown in Table 2, in the case of O_2>Ar plasma pretreatment, the roughness of the MgO layer was slightly reduced in comparison with the panel without the plasma pretreatment (Ref. panel). However, as shown in Table 2, in the both cases of Ar and Ar>O_2 plasma pretreatments, the each roughness of the MgO layer was remarkably reduced in comparison with the panel without the plasma pretreatment, implying that the physical sputtering was dominantly produced by the Ar plasma pretreatment.

3.2 Change in Firing Voltages and Address Discharge Characteristics During Panel-Aging Process

Figure 7 shows the changes in the firing voltages between the X-Y electrodes under the MgO cathode condition based on the V_t closed curve measurement during the panel-aging process for up to 6 hours on the 50-in. test panels prepared by the RF-plasma pretreatment on the MgO layer under various plasma gas compositions. As shown in Figure 7, in both cases of without the plasma pretreatment and O_2>Ar plasma pretreatment, the discharge firing voltages were observed to be reduced continuously during the panel-aging process. However, in both cases of Ar and Ar>O_2 plasma pretreatments, the discharge firing voltages were stabilized in a short period of time after the aging process started. This means that the panel-aging process times could be shortened in the cases of adopting the Ar and Ar>O_2 plasma pretreatments on the MgO surface prior to sealing process.

Figure 8 shows the changes in (a) the formative address delay time (= ΔT_f) and (b) the statistical address delay time (= ΔT_s) during the panel-aging process for up to 6 hours on the 50-in. test panels prepared by the RF-plasma pretreatment on the MgO layer under various plasma gas compositions. As shown in Figure 8 (a), in both cases of without the plasma pretreatment and O_2>Ar plasma pretreatment, the formative address delay times were observed to be increased continuously during the panel-aging process. However, in both cases of Ar and Ar>O_2 plasma pretreatments, the formative address delay times were stabilized in a short period of time after the aging process started.

As shown in Figure 8 (b), in both cases of without the plasma pretreatment and O_2>Ar plasma pretreatment, the statistical address delay times were observed to be increased

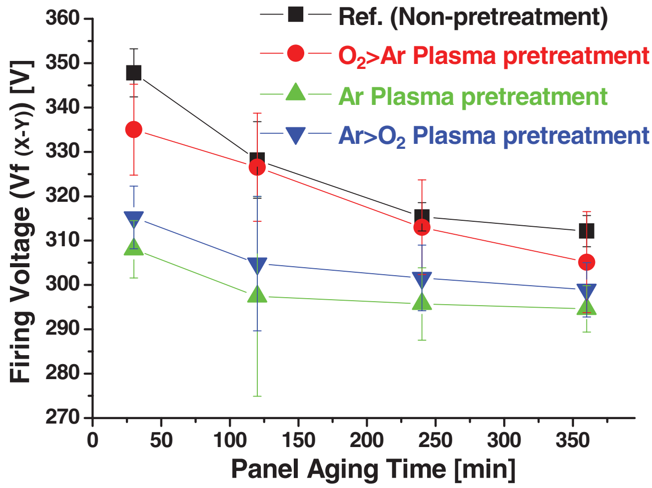

Figure 7. Comparison of firing voltages between X-Y electrodes under MgO cathode condition based on Vt closed curve relative to panel-aging time measured from 50-inch FHD panels prepared using RF-plasma pretreatment on MgO layer under various plasma gases, $O_2 > Ar$, Ar, and $Ar > O_2$.

fast during the panel-aging process. However, in both cases of Ar and $Ar{>}O_2$ plasma pretreatments, the statistical address delay times were observed to be increased gradually during the panel-aging process, when compared with those in both cases of without the plasma pretreatment and $O_2{>}Ar$ plasma pretreatment.

Figure 9 shows the changes in the wall voltage variation (ΔV_w) between the A-Y electrodes under the MgO cathode based on the V_t closed curve measurement during the panel-aging process for up to 6 hours on the 50-in. test panels prepared by the RF-plasma pretreatment on the MgO layer under various plasma gas compositions. Here, ΔV_w was defined as the difference of the wall voltages from the first to the last scan line between the A-Y electrodes [10]. As shown in Figure 9, in both cases of without the plasma pretreatment

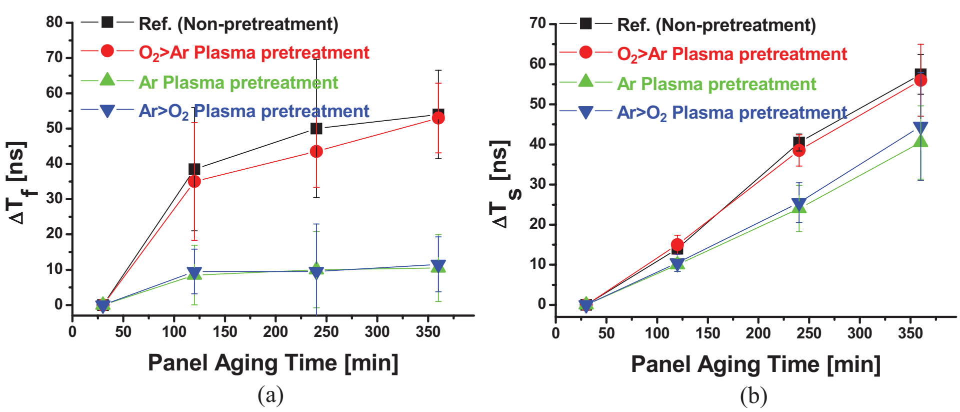

Figure 8. Comparison of address delay time differences (ΔT) relative to panel-aging time measured from 50-inch FHD panels prepared using RF-plasma pretreatment on MgO layer under various plasma gases, $O_2 > Ar$, Ar, and $Ar > O_2$. (a) Formative (ΔT_f) and (b) statistical (ΔT_s) address delay times.

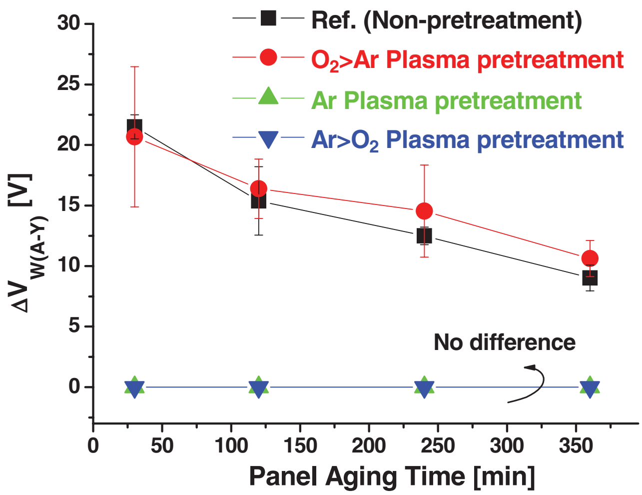

Figure 9. Comparison of wall voltage variation (ΔV_w) of A-Y plate-gap discharge under MgO cathode condition based on Vt closed curve relative to panel-aging time measured from 50-inch FHD panels prepared using RF-plasma pretreatment on MgO layer under various plasma gases, $O_2 > Ar$, Ar, and $Ar > O_2$.

and O_2>Ar plasma pretreatment, the wall voltage variations were observed to be reduced continuously during the panel-aging process. However, in both cases of Ar and Ar>O_2 plasma pretreatments, the wall voltage variations remained almost constant during the panel-aging process. Thus the physical plasma pretreatment of the MgO surface prior to the sealing process could enhance the wall charge keeping capability throughout the address procedure, which is a key factor for the stable and fast addressing of PDP, especially in FHD panel conditions.

In conclusion, the Ar and Ar>O_2 plasma pretreatments can eliminate the residual impurities on the MgO surface easily, and as such shorten the aging process time by fast stabilizing the various parameters such as the firing voltage, formative address delay time, statistical address delay time, and wall voltage variation, which are requisite for the stable discharge.

Conclusion

In this work, the RF-plasma pretreatment on the MgO layer was conducted to reduce the panel-aging process time. For both cases with and without plasma pretreatment on MgO layer in the 50-in. FHD ac-PDP, the changes in the discharge characteristics during the panel-aging process, such as a firing voltage, formative address delay time, statistical address delay time, and wall voltage variation, were examined. It was observed that in cases of Ar and Ar>O_2 plasma pretreatments, the firing voltage, formative address delay time, statistical address delay time, and wall voltage variation were stabilized in a short time after the aging process. It was concluded that the Ar and Ar>O_2 plasma pretreatments could induce the stable discharge quickly in PDP panels with very small discharge cells by reducing the organic impurities on the MgO layer easily for the fast panel-aging process.

Acknowledgment

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