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Discharge Characteristics and Fabrication Process of Face-to-Face Sustain Electrode Structure in AC-Plasma Display Panel

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This paper presents discharge characteristics and fabrication processes of the face-to-face sustain electrode structure in AC-plasma display panel. The fabrication process of the 6-in. test panels with two different types of electrodes such as face-to-face and coplanar electrodes are compared. For both structures, the discharge characteristics, such as the luminance and luminous efficiency, are compared and examined. The luminance efficiencies for two structures are measured at a 4% Xe-content and a pressure of 450 Torr, and driving frequencies of 100 kHz with a duty ratio of 40%, respectively. As a result, the luminance of the face-to-face sustain electrode structure is improved by about 3.5 to 4 times than that of the coplanar structure. The luminance efficiency of the face-to-face structure is improved by about 1.35 times than that of the coplanar structure in the 42-in. high definition (HD) grade AC-PDPs.

Keywords: AC PDP; cell structure; counter electrodes; face-to-face sustain electrodes; high luminous efficiency; long discharge path; luminous efficiency

I. INTRODUCTION

Despite their predominant position in the flat-panel large-screen (>40 inch) digital television market, plasma display panels (PDPs) still have a low luminous efficiency. To solve this problem, many researches, such as an optimization of gas chemistry including a high Xe%, a development of a new driving scheme and cell structure, have been carried out intensively. In particular, the cell structure, i.e., barrier rib structure, is an important factor for improving the

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luminous efficiency [1–3]. In this sense, the face-to-face sustain electrode structure has been suggested to improve the luminous efficiency of ac-PDPs [4]. The face-to-face sustain electrode structure has shown a high luminous efficiency due to the large sustain discharge distance [5,6] and the improvement of the transmittance for the visible emission caused by the elimination of the ITO electrode and the dielectric layer on the front panel. However, in the conventional face-to-face structure that has been reported so far has a difficulty in fabricating the sustain electrodes because the sustain electrodes are immersed inside the barrier ribs [7].

In this study, the proposed face-to-face sustain electrode structure is fabricated easily by changing only the baking temperature under the conventional manufacturing process conditions. The manufacturing process and optical and electrical characteristics of 6-in. test panels with two different types of electrodes, such as face-to-face and coplanar electrodes, are compared.

II. FABRICATION OF FACE-TO-FACE STRUCTURE

A. Structure

Figures 1(a) and (b) show the schematic diagram of a single pixel in (a) the proposed face-to-face and (b) coplanar sustain electrode structure (b) used in this study. Their detailed specifications are listed in Table 1. For both structures, the vertical and horizontal cell pitches for a single sub-pixel are 693 and 304 μm, respectively. As shown in Table 1, the width of the barrier-rib is 80 μm, the discharge gaps between the two sustain electrodes are 483 μm for face-to-face structure, and 80 μm for coplanar structure, respectively. The barrier-rib height is 120 μm and the thickness of the dielectric layer is 40 μm. An MgO protective layer with a thickness of 0.7 μm is then deposited on the dielectric layer. The gas mixture of Ne-Xe (4%) is filled under the pressure of 450 Torr in the 6-in. test panel. As shown in Figure 1(b), the coplanar sustain electrodes consist of the opaque bus electrode made from the Ag paste and the transparent ITO (Indium Tin Oxide) sustain electrodes. Whereas, for the face-to face sustain electrode, only the opaque sustain electrodes made from the Ag paste are immersed within the barrier-ribs with fine grooves fabricated by the sandblasting method, as shown in Figure 1(a).

Figure 2(a) shows the barrier rib image of the 6-in. test panel with the face-to-face sustain electrode structure on the front panel. In the face-to-face structure, the ITO electrode and the dielectric layer on the front panel are eliminated, as shown in Figure 2(a). Figure 2(b)

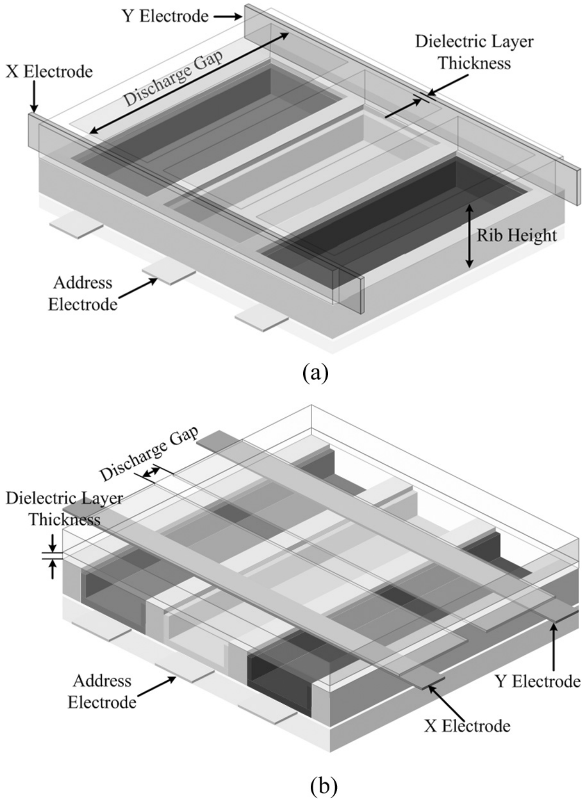

FIGURE 1 Schematic diagram of 6-in. test panels with: (a) proposed face-to-face sustain electrode and (b) coplanar sustain electrode.

TABLE 1 Comparison of Specifications between Proposed Face-to-face and Coplanar Sustain Electrode Structures

	Face-to-face sustain electrode structure	Coplanar sustain electrode structure
Discharge Gap	483 μm	80 μm
Barrier-rib Width	80 μm	
Barrier-rib Height	120 μm	
Dielectric Layer Thickness	40 μm	
Cell Pitch	693 × 304	
Gas Composition	Ne-Xe (4%), 450 Torr	

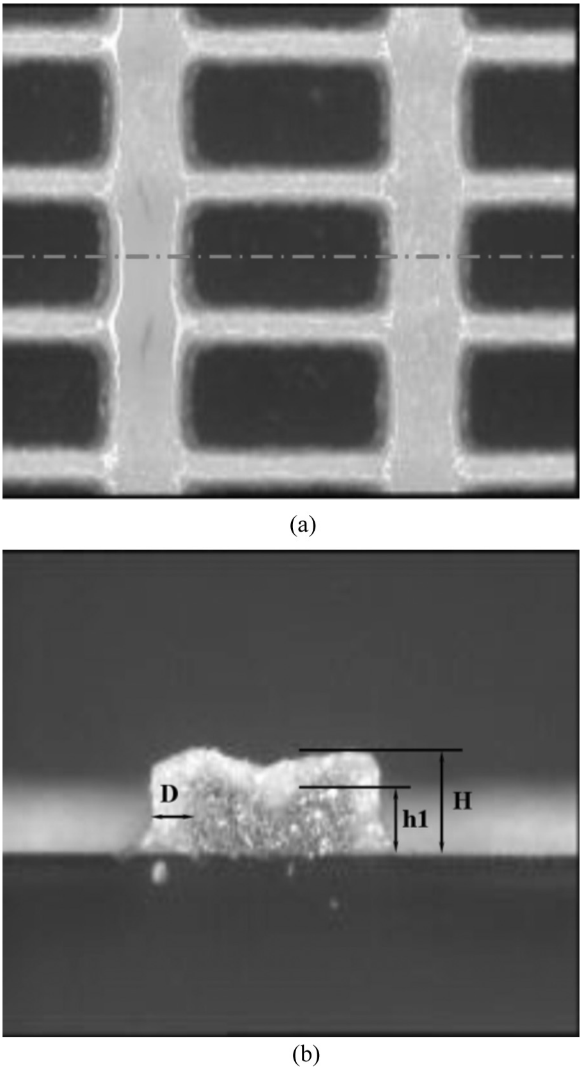

FIGURE 2 Barrier-rib image of 6-in. test panel with face-to-face sustain electrode structure.

shows the cross-sectional image of the barrier-rib of the 6-in. test panel with the face-to-face sustain electrode structure. In Figure 2(b), the barrier rib (D) with a thickness of 35 μm plays a role in the front dielectric layer in the coplanar structure. The height of the barrier-rib (H) is 80 μm, and the height of the bus electrode (h1) is 50 μm, as shown in Figure 2(b).

Figure 3(a) shows a scanning electron microscope (SEM) image of the conventional barrier-rib surface after baking. In general, for the coplanar structure, the barrier-rib surface is porous, as shown in Figure 3(a). However, for the face-to-face structure, since the barrier-rib should play a role in the front dielectric layer, such a porous barrier-rib cannot be adopted. Accordingly, the smooth and

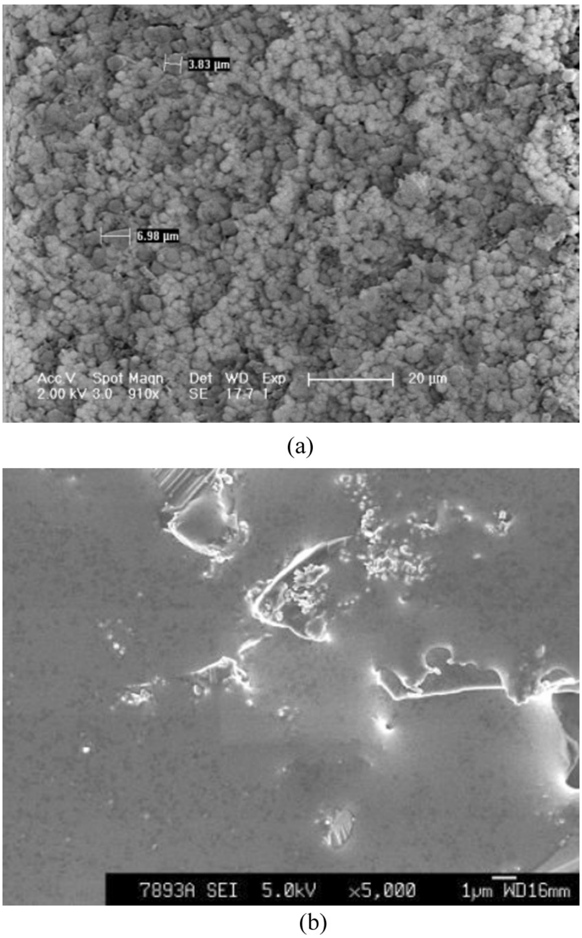

FIGURE 3 Scanning electron microscope (SEM) images of barrier-rib surfaces after backing: (a) porous conventional barrier rib, and (b) smooth and compact barrier for face-to-face structure.

TABLE 2 Fabrication Conditions of barrier-Rib in Figure 3

	Porous barrier-rib	Compact barrier-rib
Backing temperature	585°C	600°C
Backing time	3 hours	5 hours
materials	PbO-B2O_3-SiO_2, Al_2O_3, TiO_2, and Pigment	

compact barrier-rib surface is necessary for the face-to-face structure. Figure 3(b) shows the SEM image of the smooth and compact barrier-rib surface suitable for the face-to-face structure. Since the sustain electrode is immersed within the barrier-rib for the face-to-face structure, the smooth and compact barrier-rib surface can suppress the breakdown phenomenon under high voltage. The smoothness and compactness of the barrier-rib surface strongly depends on the backing temperature, backing time, and materials. Under the same materials, the barrier-rib surface becomes smoother and denser in proportion as the backing temperature and backing time are increased. The detailed fabrication conditions are listed in Table 2.

B. Fabrication Process

Figures 4(a) and (b) show the fabrication processes of front glass for both structures: (a) the coplanar and (b) the face-to-face sustain electrode structures. For the coplanar structure, the front-plate manufacture begins with the pattering process of the indium-tin-oxide (ITO). First, a dry film resist (DFR) is laminated and patterned on the ITO-coated front glass, as shown in (i) and (ii) of Figure 4(a). Then, in (iii) of Figure 4(a), the ITO electrodes are patterned by the wet etching process. Next, the bus electrodes are printed by the screen printing method after eliminating DFR, as shown in (iv) and (v) of Figure 4(a). Finally, in (vi) of Figure 4(a), the transparent dielectric paste is printed with a thickness of 40 μm by the screen printing method. Meanwhile, for the face-to-face structure, the barrier-rib paste is printed with a thickness of 60 μm on the front glass, as shown in (i) of Figure 4(b). Like the process of (ii) in Figure 4(a), a dry film resist (DFR) is laminated and patterned on the barrier-rib, in (ii) of Figure 4(b). After that, the barrier-rib is patterned by the sand-blasting method, such that the narrow gaps are formed in the barrier-rib, as shown in (iii) of Figure 4(b). The narrow gap in the barrier rib is filled with the Ag paste by the screen printing method after removing the DFR, as shown in (iv) of Figure 4(b). Then, to make a discharge space,

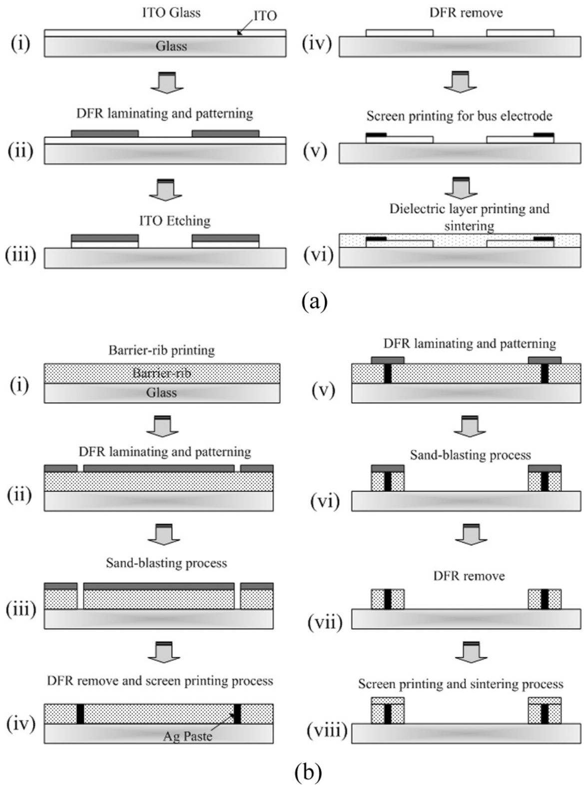

FIGURE 4 Fabrication process of front glass: (a) coplanar, and (b) face-to-face sustain electrode structure.

the DFR is again laminated and patterned like (v) of Figure 4(b). The barrier-rib is physically etched by the sand-blasting process, as shown in (vi) of Figure 4(b). After that, the DFR is removed in (vii) of Figure 4(b). To prevent the exposure of the electrode, the barrier-rib is printed on the Ag electrodes by the screen printing process, as shown in (viii) of Figure 4(b). Finally, the front glass is sintered at 600°C for about 5 hours.

For the coplanar structure, there are two-step baking processes: one-step baking process is to bake the front glass after patterning the bus electrodes and the other-step backing process is to bake the front glass after printing the front transparent dielectric layer. However, for the face-to-face structure, only one baking process is adopted at the final step, as mentioned in (viii) of Figure 4(b), because all manufacturing processes consist of drying processes.

Accordingly, the time required for the fabrication of the face-to-face structure can be reduced in comparison of that of the coplanar structure. For the rear glass processes, the fabrication for both structures is identical. First, the address electrodes are printed by screen-printing method. And the address electrodes are covered by reflective layer. The red, green, and blue phosphor layers are screen-printed between the barrier ribs, with a thickness of 15–20 μm. Then, the phosphor layer is baking process is performed. In general, the height of the barrier-rib is 120 μm for the coplanar structure. However, the height of the barrier-rib in the face-to-face structure is 50 μm.

III. DISCHARGE CHARACTERISTICS

A. Measurement

Figure 5 shows a schematic diagram of the optical and electrical system for measuring the luminance and power consumption in the 6-in. test panel utilized in this study. This measurement system consists of 6-in. test panel, a driving circuit system, an ampere-meter, an oscilloscope, and a spectrometer. The driving circuit system consists of the driving circuit, power supply and signal generator. The sustain electrodes, X and Y are supplied by the electrical pulses generated from the driving circuit, and the resultant sustain pulses, Vx and Vy are alternately applied at a driving frequency of 100 kHz with a duty ratio of 40%.

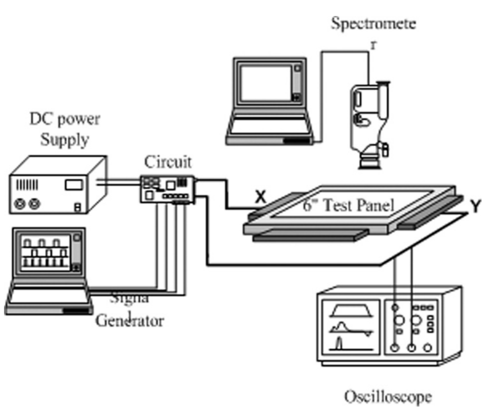

FIGURE 5 Schematic diagram of experimental setup.

B. Luminance and Luminous Efficiency

Figures 6(a) and (b) show the changes in the luminance and luminous efficiency relative to the sustain voltage for both structures. As shown in Figure 6(a), the luminance in the face-to-face structure is improved by about 3.5 times than that in the coplanar structure. The low sustain voltage is 160 V for coplanar structure, whereas the low sustain voltage is 240 V for face-to-face structure, as shown in Table 3. This phenomenon is due to the longer discharge gap (= 483 mm) of the face-to-face structure than that (= 80 mm) of the coplanar case. The test panels were used to measure the luminance and the power consumption.

The luminous efficiency was obtained from the following equation:

$$\eta = \frac{\pi BA}{P} = \frac{\pi BA}{V_S(I_{on} - I_{off})}$$

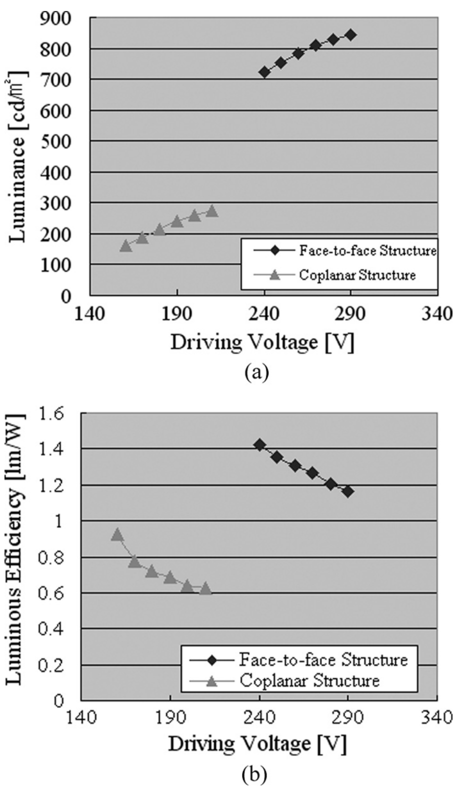

FIGURE 6 (a) Luminance and (b) luminous efficiency for both structures: face-to-face and coplanar sustain electrode structures.

TABLE 3 Comparison of Firing and Sustain Voltages for Both Structures

	Face-to-face sustain electrode structure	Coplanar sustain electrode structure
First On	290 V	210 V
First Off	240 V	160 V

where η is a luminous efficiency, B is a luminance, A is a display area, and P is the power consumption considering both the sustain and address currents. In the above equation, Vs is input sustain voltage, I_{on} is discharge current, and I_{off} is displacement current. As shown in Figure 6(b), the luminous efficiencies are obtained at 1.42 lm/W at a sustain voltage of 240 V for face-to-face structure, and at 0.92 lm/W at a sustain voltage of 160 V for coplanar structure. As a result, the luminous efficiency of the face-to-face structure is improved by about 1.35 times than that of the coplanar structure.

IV. CONCLUSION

This paper presents discharge characteristics and fabrication processes of the face-to-face sustain electrode structure in AC-plasma display panel. The fabrication process of the 6-in. test panels with two different types of electrodes such as face-to-face and coplanar electrodes are compared. For both structures, the discharge characteristics, such as the luminance and luminous efficiency, are compared and examined. The luminance efficiencies for two structures are measured at a 4% Xe-content and a pressure of 450 Torr, and driving frequencies of 100 kHz with a duty ratio of 40%, respectively. As a result, the luminance of the face-to-face sustain electrode structure is improved by about 3.5 to 4 times than that of the coplanar structure. The luminance efficiency of the face-to-face structure is improved by about 1.35 times than that of the coplanar structure in the 42-in. high definition (HD) grade AC-PDPs.

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