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Influence of Al_2O_3 reflective layer under phosphor layer on luminance and luminous efficiency characteristics in alternating-current plasma display panel

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ABSTRACT

This paper examines the optical and discharge characteristics of alternating-current plasma display panel when adopting the Al_2O_3 reflective layer. The Al_2O_3 reflective layer is deposited under the phosphor layer by using the screen-printing method. The resulting changes in the optical and discharge characteristics, including the power consumption, color temperature, luminance, luminous efficiency, scanning electron microscopy image, and reflectance, are then compared for both cases with and without Al_2O_3 reflective layer. As a result of optimizing the thicknesses between the Al_2O_3 and phosphor layers, the luminance and luminous efficiency are improved by about 17% and 7%, respectively.

1. Introduction

It is well known that alternating-current (AC) plasma display panels (PDPs) are a promising technology for large area flat panel displays and have reached the early commercialization stage. However, PDPs have some problems, such as lower luminance and luminous efficiency. Accordingly, improving the luminance and luminous efficiency is a key factor for a better panel performance in PDP. These improvements will be made by the optimization and development of cell geometry [1], gas composition [2,3], high Xe content [4], driving waveform [5], sealing method [6], plasma pretreatment [7], electrode materials, phosphor materials, and protective layers [8–11].

The luminance of a visible light emitted through the front panel of PDPs is obtained as a result of visible conversion of the phosphor layer deposited on the barrier rib in the rear panel of PDPs. In the current PDPs with reflective structure, the leakage of a visible light emitted from the phosphor layer into the real panel is unavoidable, even though the phosphor layer plays a little role in reflecting the visible light. Our experimental result shows that the reflectance of the phosphor layer with a thickness of 10–15 μm was about 60–70%. If the thickness of phosphor layers was increased to enhance the reflectance, the production of vacuum ultraviolet would be reduced due to the shrinkage in the discharge space. This means that the reflective layers need to be studied in order to minimize the loss of the visible light emitted from the phosphor layer without sacrificing the discharge space.

However, the electro-optical properties using the reflective layer under the phosphor layer have not yet been studied.

In this paper, the two reflective layers, TiO_2 and Al_2O_3 layers are examined to check which layer is suitable for increasing the reflectance of the visible light emitted from the phosphor layer during sustain discharge. Furthermore, this paper examines the influences of the reflective layers under the phosphor layer on the luminance and luminous efficiency by adjusting the thicknesses between the reflective layer and phosphor layer in the 50-in. full-high definition (FHD) AC-PDP with Ne-He (61%)-Xe (15%) contents.

2. Experimental Set-up

Fig. 1 shows the optical-measurement systems and commercial 50-in. FHD test panel with three electrodes used in the experiments, where X is the sustain electrode, Y is the scan electrode, and A is the address electrode. A color analyzer (Konika Minolta, CA-100 plus), pattern generator, signal generator (Future Technology Laboratory, UDS 3.0), current probe (LeCroy, AP015), and photo-sensor amplifier (Hamamatsu, C6386) were used to measure the luminance, color temperature, and power consumption, respectively. In this experiment, for the front glass plate, the MgO thin film was deposited on the dielectric layer of the AC-PDP by using ion-plating evaporation and the oxygen and hydrogen flow rates were kept at 180 and 60 sccm, respectively, during the deposition. Whereas, for the rear glass plate, the phosphor layer was deposited on the rear dielectric layer and barrier rib.

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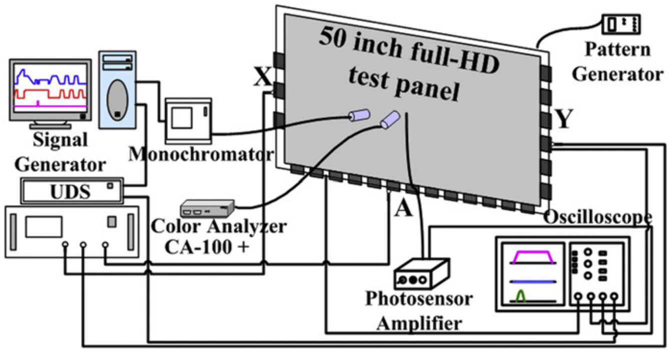

Fig. 1. Schematic diagram of experimental setup employed in this study.

Fig. 2 shows the partial schematic diagram in the cross section of the proposed reflective layer under the phosphor layer of the rear glass plate in 50-in. FHD test panel. As shown in Fig. 2, the reflective layer was deposited under the phosphor layer by using the screen-printing method.

Fig. 3 shows the applied driving waveforms, including the reset, address, and sustain periods. The frequency for the sustain period was 200 kHz. A driving method with a selective reset waveform was also adopted, and the gas chemistry in the experiment was Ne–Xe (15%)–He (61%) under a pressure of 56 kPa. Table 1 lists the detailed specifications for the all the test panels, which were exactly the same, except for the phosphor layer with and without reflective layers.

3. Results and discussion

Fig. 4 shows the cross-sectional scanning electron microscopy (SEM) images of the TiO_2 and Al_2O_3 reflective layers deposited on the single glass plate without the phosphor layer. The SEM examinations were performed on a Hitachi S-4200 SEM at 5 kV. As shown in Fig. 4(a), the shape of TiO_2 reflective layer was globular, which is similar to that of the phosphor layer, whereas, as shown in Fig. 4(b), the shape of Al_2O_3 reflective layer was flaky.

Fig. 5 shows the changes in the reflectance of the TiO_2, Al_2O_3 reflective layers, and phosphor layer deposited on the single glass plate under various thicknesses of the single layer, which were measured by use of a spectrophotometer (Konica Minolta, CM-2600d). As shown in Fig. 5, the reflectance in the Al_2O_3 reflective layer with the flaky shape was higher than that in the TiO_2 reflective layer with the globular shape. Since the permittivity of the Al_2O_3 layer is similar to that of the TiO_2 layer, the difference of the reflectance between the Al_2O_3 layer and TiO_2 layer would be presumably due to the shape of the reflective layers; that is, a flaky shape for the Al_2O_3 layer, whereas a globular for the TiO_2 layer. However, this higher reflectance characteristic of the Al_2O_3 layer is still unexplained, and requires a further

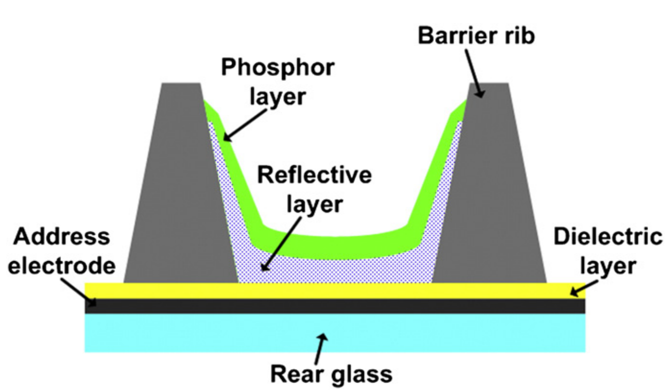

Fig. 2. Partial schematic diagram (in cross section) of reflective layer under phosphor layer of rear panel structure in 50-in. FHD AC-PDP.

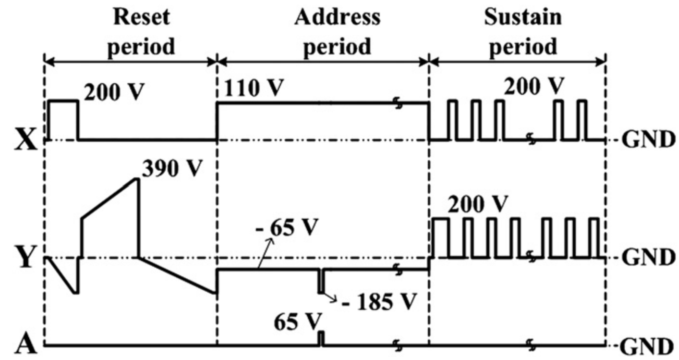

Fig. 3. Schematic diagram of driving waveform employed to measure optical and discharge characteristics during reset, address, and sustain period.

study. Nonetheless, according to the experimental result of Fig. 5, the Al_2O_3 reflective layer was proposed to further enhance the reflectance of the visible light emitted from the phosphor layer on the 50-in. FHD test panel.

Fig. 6 shows the plane and cross-sectional SEM images of the Al_2O_3 reflective layer on the rear dielectric layer measured from the 50-in. FHD test panels. As shown in Fig. 6, the Al_2O_3 reflective layer showed the flaky shape. Table 2 shows the different thickness ratios between the Al_2O_3 layer and the phosphor layer deposited in the 50-in. FHD test panel. The thickness combination between the two layers in Table 2 was chosen in order not to change the discharge space with respect to the reference case. The reference case here means that only the phosphor layer was deposited to a thickness of about 10 μm on the rear dielectric layer and barrier rib without the Al_2O_3 reflective layer. Case 1 means that the Al_2O_3 reflective layer was deposited about 5 μm on the rear dielectric layer and barrier rib, and then the phosphor layer was deposited about 5 μm on the Al_2O_3 reflective layer. Case 2 means that the Al_2O_3 reflective layer was deposited about 10 μm on the rear dielectric layer and barrier rib, and then the phosphor layer was deposited about 5 μm on the Al_2O_3 reflective layer.

Fig. 7 shows the changes in the luminance, power consumption, and ratio of the luminance to the power consumption measured from the 50-in. FHD test panels under various thicknesses of the Al_2O_3 reflective layer and phosphor layer. As shown in Fig. 7(a), for cases 1 and 2, the luminance was considerably increased in comparison with the panel without the Al_2O_3 reflective layer, which was mainly due to the improvement of the visible light emitted from the phosphor layer caused by the Al_2O_3 reflective layer with an increased reflectance. Whereas, as shown in Fig. 7(b), for cases 1 and 2, the power consumption was slightly increased. However, as shown in Fig. 7(c), for cases 1 and 2, the ratios of the luminance to the power consumption were increased by about 4 and 7%, respectively, in comparison with the panel without the Al_2O_3 reflective layer in the 50-in. FHD test panels. This result indicated that the luminous efficiency was also increased in the case of adopting the Al_2O_3 reflective layer.

Fig. 8 shows the changes in the color temperature measured from the 50-in. FHD test panels under various thicknesses of the Al_2O_3 reflective layer and phosphor layer. Cases 1 and 2 in Fig. 8 illustrated that the color temperatures were increased in comparison with the panel without the Al_2O_3 reflective layer. Hence, the application of

Table 1
Specifications of 50-in. 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 (15%)–He (61%)	
Gas pressure		56 kPa	

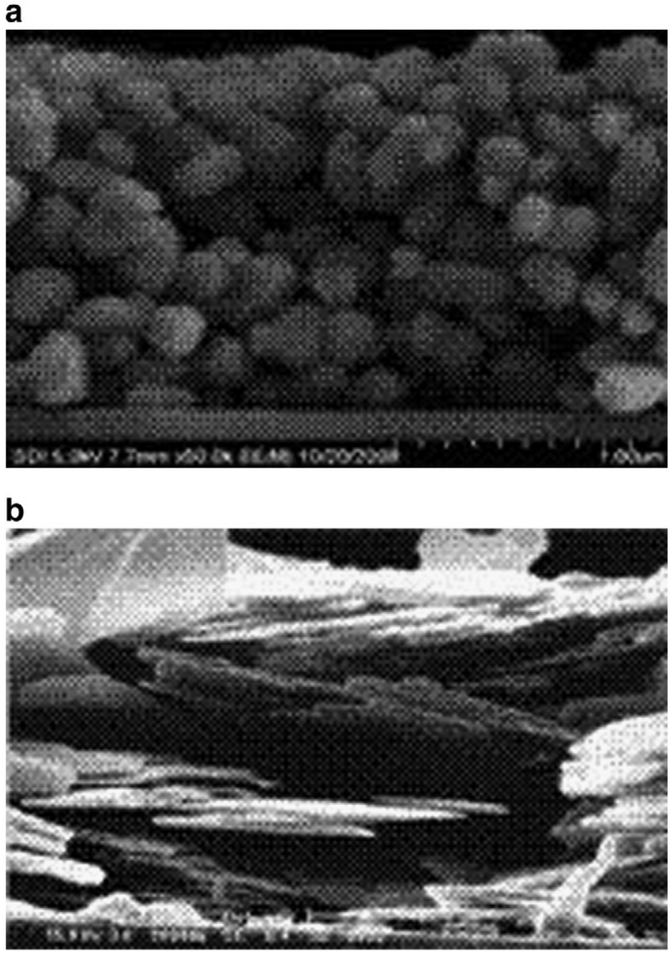

Fig. 4. Comparison of cross-sectional SEM images of (a) TiO_2 and (b) Al_2O_3 reflective layers deposited on single glass plate.

the Al_2O_3 reflective layer proposed in this experiment would be expected to help enhance of the luminance, luminous efficiency, and color temperature in PDP-TVs.

4. Conclusion

In summary, this paper investigates the changes in the optical and discharge characteristics in AC-PDP when adopting the TiO_2 and Al_2O_3 layers as reflective layers under the same phosphor layer. The Al_2O_3 layer with flaky shape was observed to be suitable reflective

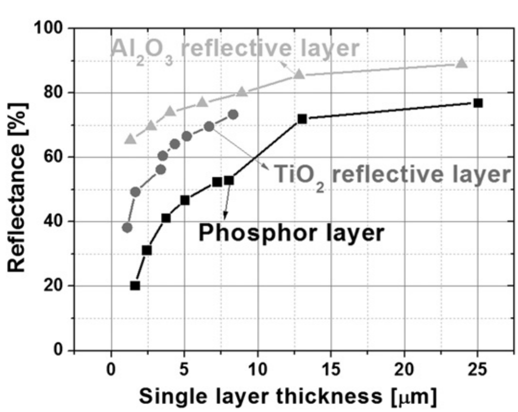

Fig. 5. Change in reflectance of TiO_2, Al_2O_3 reflective layers, and phosphor layer deposited on single glass plate under various thicknesses of single layer.

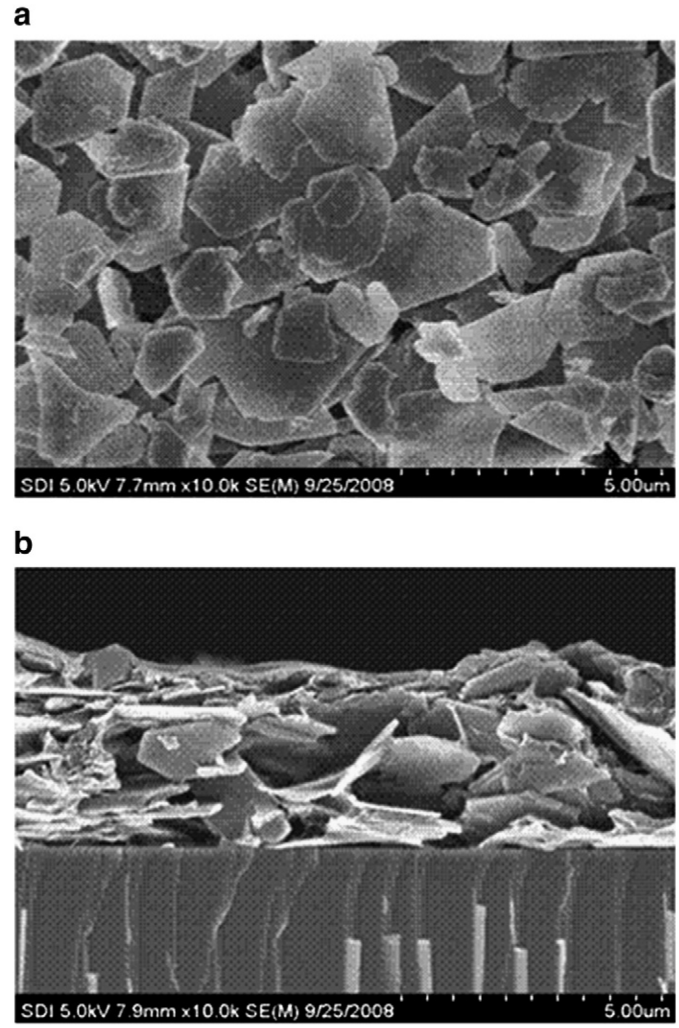

Fig. 6. Comparison of (a) plane and (b) cross-sectional SEM images of Al_2O_3 reflective layer measured from 50-in. FHD test panels.

layer for reducing the loss of the visible light emitted from the phosphor layer on the 50-in. FHD test panel as compared with TiO_2 reflective layer. The changes in the optical and discharge characteristics, including the power consumption, color temperature, luminance, luminous efficiency, SEM image, and reflectance, are examined for two cases with different thicknesses of Al_2O_3 reflective layers, and also compared for the reference case without Al_2O_3 reflective layer. As a result, our experimental results confirm that the Al_2O_3 reflective layer with flaky shape is very effective in enhancing the luminance, thereby increasing the luminous efficiency. Thus, it is concluded that Al_2O_3 reflective layer can enhance optical characteristics, such as color temperature, luminance, and luminous efficiency.

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Table 2
Different thicknesses of Al_2O_3 reflective layer and phosphor layer deposited to test panels.

	Ref.	Case 1	Case 2
Al_2O_3 reflective/phosphor layer thickness [μm]	0 μm/10 μm	5 μm/5 μm	10 μm/5 μm

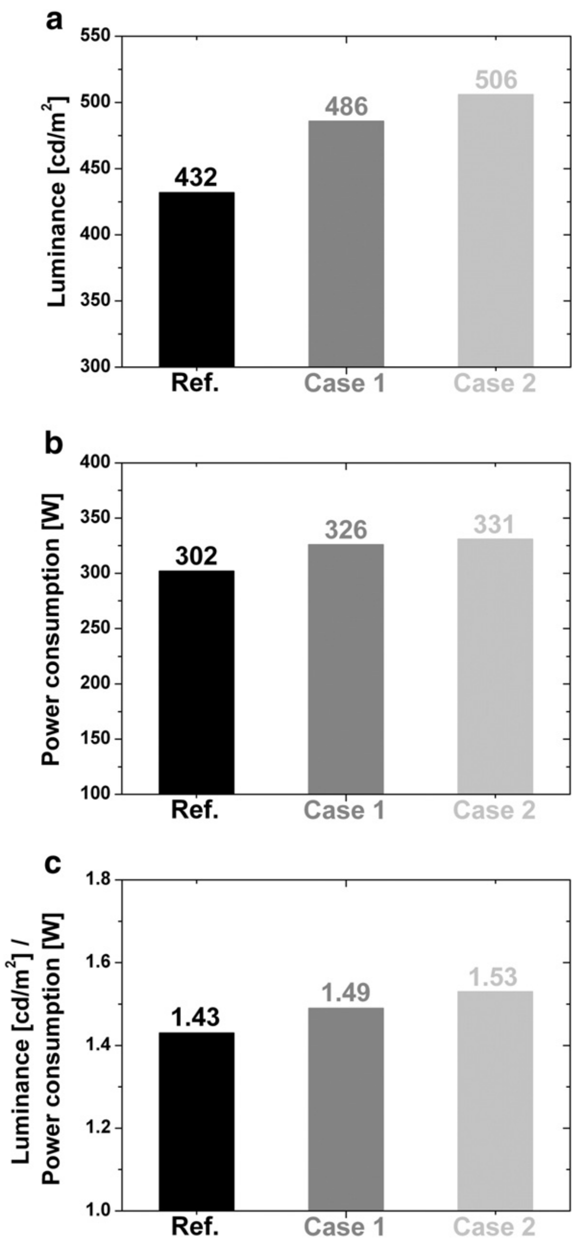

Fig. 7. Change in (a) luminance, (b) power consumption, and (c) ratio of luminance to power consumption measured from 50-in. FHD test panels under various thicknesses of Al_2O_3 reflective layer and phosphor layer.

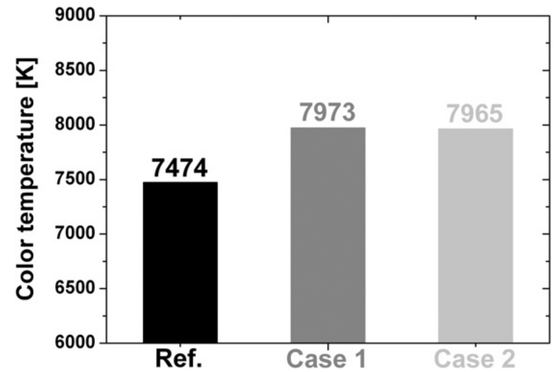

Fig. 8. Change in color temperature measured from 50-in. FHD test panels under various thicknesses of Al_2O_3 reflective layer and phosphor layer.

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