Developments of Transparent ac-PDPs

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Abstract

Transparent ac-PDP test panel was prepared via a combination of materials including ITO sustaining electrodes, thin film dielectric layer and nano-sized phosphor powders. The thin film dielectric layer was prepared by E-beam evaporation process and phosphor layer was deposited on metal mesh pattern by electrophoretic deposition process. The optical transmittance and luminance of the panel indicated that full color transparent ac-PDP is feasible with the approach.

1. Introduction

With ever-increasing competition among various flat panel devices for market shares in TV application, new applications of flat panel devices are being explored actively to support sustained growth of the industries. Especially, ac-PDP industries which rely mainly on TV applications need other profitable applications to offset the decreasing selling price of the device. For the new applications, various other features including flexibility and transparency of the panels are being required. Among them, we noted that optical transparency of ac-PDPs could become its exclusive characteristics.

The transparent displays do not pose any obstacle for user's vision. The conventional opaque display device divides the spaces, obstructing the field of vision. Potential applications of such transparent displays include window displays, table displays, windshield vehicle displays, etc. With the transparent displays, information can be provided to users without hindering the field of vision of users.

Several transparent information display devices are currently being developed, including OLED with oxide TFTs, inorganic LED, and electro-wetting displays. Those displays, however, are at early stages of developments and may require further studies for actual applications. When Prof. Bitzer and Slottow developed ac-PDP in 1964, on the other hand, it was in a form of transparent device[1]. The device was a transparent gas discharge monochromatic panel, but later transformed into an opaque device to realize full-color images by phosphor layer.

In order to make the ac-PDPs transparent with capability of full-color images, several modifications must be made to current structures and materials used in the devices. Firstly, the optical transmittance of glass dielectric layer must be improved significantly. The transmittance of glass dielectric layer being used currently for ac-PDPs is about 70% [2]. If front and rear glass layers are used together, optical transmittance of the panel would become less than 50%. In general, transparent displays require optical transmittance better than 70%, preferably better than 80%. Thus, the optical transmittance of glass dielectric layer must be improved significantly.

Secondly, the optical transmittance through the phosphor layer must be improved significantly also. For this, several approaches could be used: thin film phosphors, nano-sized phosphor powders layers, and no-phosphor layer at see-through areas. Thin film phosphors has a high optical transmittance [3], but its optical efficiency is expected to be rather low since the interaction volume the film would be small. In addition, the film is hard to form R, G, B primary phosphor patterns separately for each pixel.

The use of nano-sized phosphor powders, on the other hand, may lead to better optical efficiency of

VUVs. In the case, scattering of visible lights by the powders must be considered. As the scattering is inversely proportional to seventh power of powder diameter[4], the smaller the phosphor powder size, the better will be the optical transmittance.

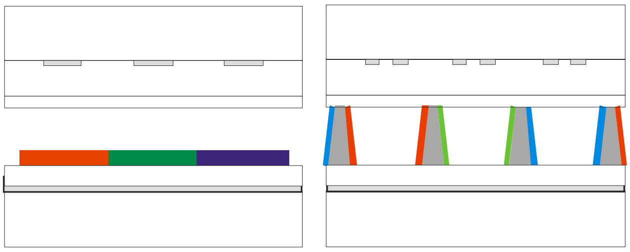
Finally, the removal of phosphor layer from the see-through areas requires new design of discharge cell structures. For this structure, the discharge cells of SM PDP[5] could be utilized. In this structure, phosphors are only coated on the surface of a phosphor plate (shadow mask plate in SM PDPs) and the other areas are kept transparent to visible lights. For this approach, the cell opening ratio of the phosphor plate should be much larger than the SM PDPs, preferably over 80%.

Based on these backgrounds, we attempted various approaches to make ac-PDPs transparent and demonstrated a possibility of transparent ac-PDPs.

2. Experimental

Figure 1 shows two schematic illustrations of transparent ac-PDP structures investigated in this study. Fig. 1(a) uses the nano-sized phosphor layer printed on the surface of rear plate. In this case, glow discharges are induced between opposing electrodes formed on front and rear glass substrates. For Fig. 1(b) structure, a phosphor plate was inserted between the front and rear glass substrates and the discharge scheme used in typical coplanar ac-PDPs was used. In this case, conventional phosphor powders were coated on the phosphor plate. The phosphor plate was prepared by chemically etching an aluminum plate of 100 μm thick. The cell opening ratio of the plate was adjusted from 60 to 85%.

In those structures, the glass dielectric layers on rear and front plates were formed via e-beam evaporation process in order to improve their optical transmittance. The glass dielectric layer formed through conventional thick film processes contains a significant fraction of sub-micrometer size pores trapped during sintering of glass frits and it is very difficult to obtain optical transmittance higher than 80%. Thus, in this study, the layer was formed by physical deposition of pyrex glass using e-beam evaporation process. The thickness of the layer was 3-4 μm. The glass layers deposited was subsequently coated with MgO thin film by e-beam evaporation process.



(a) (b)

Fig.1. Schematic illustrations of transparent PDP structure: (a) oposed discharge structure and (b) coplanar surface discharge structure

After the preparation of front and rear plates, they were sealed together to form transparent ac-PDP test panels of 1 inch in diagonal. Optical transmittance and luminance of the panels were evaluated.

3. Results and discussion

3.1 Opposed structure transparent PDP

For this structure, green phosphor powders (Zn_2SiO_4:Mn) of less than 1μm in diameter was coated on the surface of rear plate of the test panels. Luminance of the panels was measured either from the front glass plate surface or from the rear glass plate surface. As shown in Fig. 2, the luminance increased with increasing phosphor thickness but in different trends depending on measuring surface.

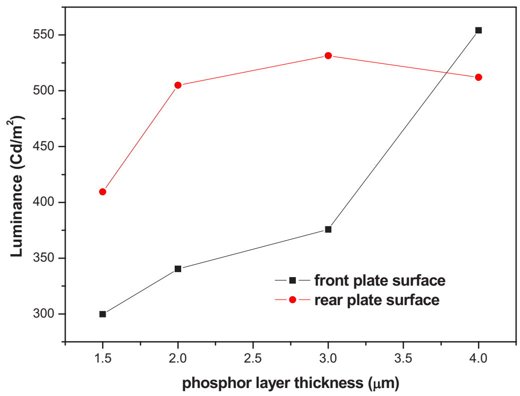


Fig2. Luminance for the phosphor coating thickness

When measured from front plate surface, the luminance increased proportionally with the coating thickness. The luminance measured from rear plate surface reached a maximum around 3μm and then decreased as the thickness increased further. This reduction in luminance is caused by decreased optical transmittance through the phosphor layer. With this structure, rather high luminance in a range of 300-500 cd/m^2 was obtained.

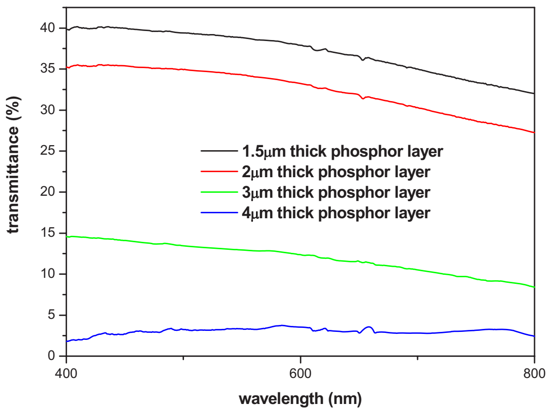


Fig. 3. Effects of phosphor layer thickness on optical transmittance

Figure 3 shows the effect of phosphor layer thickness on optical transmittance of the rear plate. The measurement was conducted by coating the layer on glass substrate for various thicknesses. As noted from the figure, the transmittance decreased from 40% to about 3% as the thickness becomes thicker from 1.5µm to 4 µm. Although this 40% optical transmittance and 300-400 cd/m^2 luminance is rather high compared with the transparent OLED, the result suggests that it would be very difficult to have high luminance as well as high optical transmittance (better than 70%) simultaneously with this structure. For this structure feasible, the phosphor powders of diameter of less than 100nm with good quantum efficiency must be developed.

3.2. Coplanar surface discharge transparent PDP

Fig. 4 shows SEM micrographs of phosphor plate manufactured by chemical etching of 100 µm thick aluminum plate. The phosphor plate was etched to have rectangular openings as well as to have isotropic etching cross section. As noted from the figure, the phosphor plate was etched uniformly and has large area of phosphor coating at its side walls. This microstructure was achieved by etching the plate from one side only. The phosphor plates were designed to have three different cell opening ratios: 60, 70, and 80%, respectively.

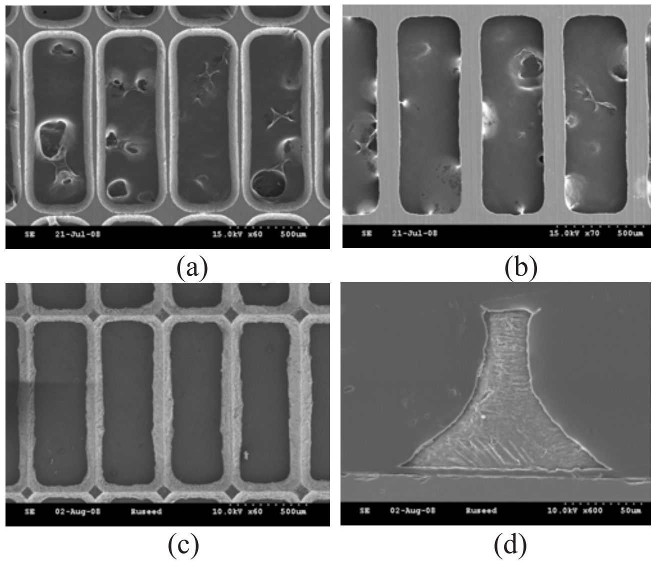


Fig. 4. SEM micrographs of a phosphor plate: (a) front view, (b) rear view, (c) after phosphor coating, and (d) cross section.

Figure 5 shows the optical transmittance of the phosphor plate with different cell opening ratio. As noted, optical transmittance increased with the cell opening ratio, suggesting that it would be feasible to achieve high optical transmittance with phosphor plate when cell opening ratio is high.

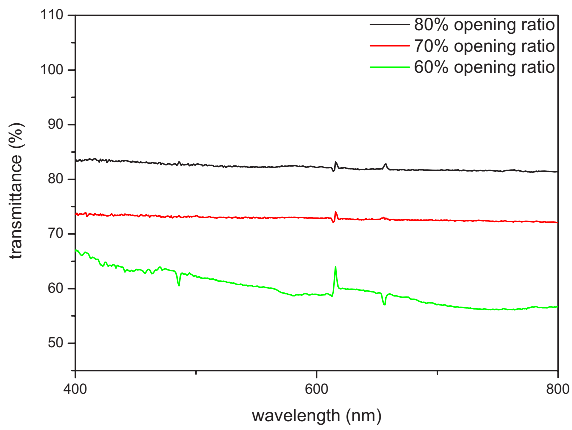


Fig. 5. Transmittance result as opening ratio of metal barrier ribs

Fig. 6 shows the optical transmittance of the test panel with thin film glass dielectric layer. The optical transmittance of the glass dielectric layer was close to 100% and the panel transmittance was slightly larger than 60%.

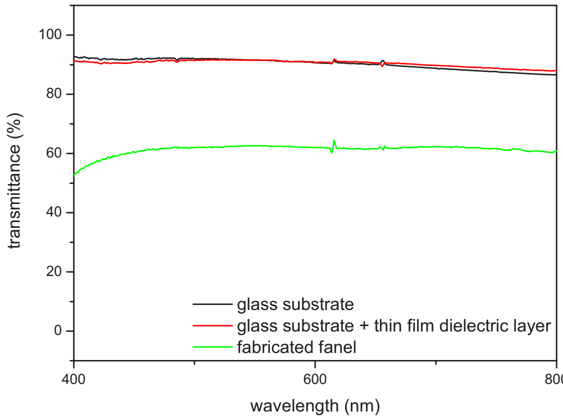


Fig.6. Optical transmittance of test panel

Fig. 7 shows the test panel operating at 120V and 200V. The First on voltage was 145V and the First OFF voltage was 160V. The panel operating at 120V has relatively low luminance and its background image can be observed through the operating panel. A possibility of transparent ac-PDP with full-color capability was demonstrated in this study for the first time.

(a) (b)

Fig7. Test panels of transparent ac-PDPs operating (a) at 120V and (b) at 200V.

The luminance of the panel operating at 200V was 150cd/m^2, but that was so bright that it blocks the images from background. This result suggests that we may need transparent displays with low luminance with high efficiency.

In order to find out the mechanism of visible light emission in our test panels, the discharge cells were examined as a higher magnification. As shown in Fig. 7, the glow discharge occurred between the sustaining electrode (yellow emission at the center of discharge cells) and the phosphor coated on the surface of phosphor plate were excited by the discharge to emit the green light.

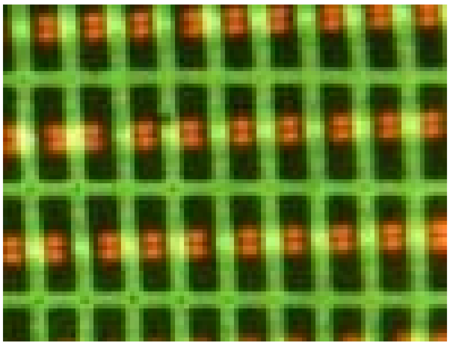


Fig.8. Detailed view of discharge phenomenon of transparent ac-PDPs.

4. Summary

In this study, a possibility of transparent ac-PDPs was explored. Test panel was prepared via a combination of materials including ITO electrodes, thin film dielectric layer and phosphor on phosphor plate. The combination resulted in test panels capable of producing full-color images. The test panels produced has optical transmittance better than 60%, These results demonstrated a possibility of full-color ac-PDPs, expanding applications of the devices.

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6. References

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