High Luminous Efficacy AC-PDP with Long Discharge Gap and Grooved Dielectric Structure

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Abstract

In this study, a high luminous efficacy AC-PDP panel with long discharge gap and grooved dielectric layer has been studied. By applying this high efficacy concept and optimized driving waveform featuring negative biased sustain, ~2.6lm/W of luminous efficacy was achieved in 42-inch HD panel. Modified fabricating process and new discharge cell structure were investigated to obtain improved uniformity and operating characteristics.

1. Introduction

Recently, major developments in the technology of plasma display panels(PDPs) permitted the production of large-area wall-mountable displays for high-definition televisions.[1] Improvement of luminance and luminous efficacy of PDP is one of the most important issues to compete with other large size flat panel displays such as LCD. To achieve this purpose, many approaches have been researched, such as various gas mixtures, new cell structures and materials. In this paper, the high efficacy concept of long discharge gap has been applied along with grooved dielectric layer, and a new driving waveform has been also developed, and the efficacy, uniformity and operating characteristics were observed.

L. F. Weber[2] suggested that long discharge gap can improve the luminous efficacy by dissipating larger portion of input energy into positive column discharge, which is much more efficient region compared to negative glow discharge. [3] [4] However, the increase of the operating voltage due to the long discharge gap has been the obstacle to commercial application. [5] By applying grooved dielectric layer structure along with long discharge gap, we could fabricate a panel with reasonable operating voltage and high luminous efficacy.

2. Experimental

The experiments were done both in 7.5” test panels and 42” commercial grade panels. The cell structure is normal coplanar structure with a pair of sustain electrodes on the front glass plate made of transparent indium-tin-oxide (ITO) films backed up with metallic bus electrodes. The discharge gap between ITO electrodes is ranging from 250 ㎛ to 400 ㎛. The ITO electrodes are covered by grooved dielectric layer, with groove depth of 15~40 ㎛ and width of 250~300 ㎛. An MgO film is applied on the dielectric layer surface as a protective layer. The barrier rib structure is rectangular shaped, formed on the white back dielectric material and coated with phosphor.

Major design specifications, like ITO electrode gap, bus electrode position and width, depth and width of groove in dielectric layer, discharge gas composition, characteristics of dielectric materials and the shape of electrodes were fabricated into 7.5” test panels to establish the effect of each factor. By observing the performance of those 7.5” test panels, the main design factors were selected and applied to 42” panels. The optimization of those design factors were done with 42” panel, along with modification of fabricating process.

3. Results and discussion

As mentioned above, the grooved dielectric layer was adopted to decrease the operating voltage of PDP with long discharge gap.[6] The effect of grooved dielectric layer on voltage was measured by Vt closed curve measurement. The surface discharge firing voltage was lowered by 45V while the vertical discharge firing voltage was not changed. The sustain minimum voltage was also lowered by 20V with grooved dielectric layer.

By applying grooved dielectric layer structure, not only the operating voltage is lowered but also the discharge mode is changed. A series of ICCD images are shown in Figure 1.

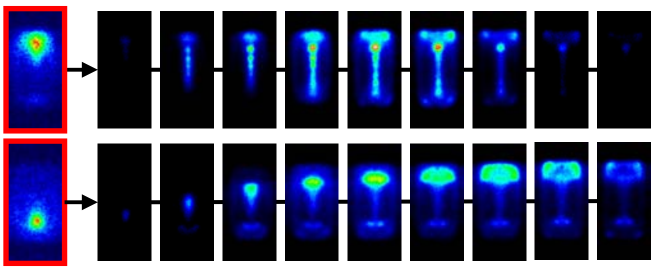

Fig. 1. ICCD images of discharge in PDP cell (Top: Conventional dielectric layer; Bottom: Grooved dielectric layer)

First picture in each row is showing the discharge starting stage in each panel. As shown in the images, IR emission appears in cathode side for normal dielectric layer while it appears in anode side for grooved dielectric layer. This indicated the discharge mode of each panel. In Figure 2, the difference between these discharge modes is shown. For surface-only discharge mode, discharge starts as a Townsend discharge in which the space charge density is too low to distort electric field induced by applied voltage and wall voltage. The IR emission in this case is from anode side where the electrons first attracted, so the first IR emission is observed in anode side in the IR image taken from the top side as in the ICCD pictures of grooved dielectric layer. For vertical-triggering discharge mode, the same principle can be applied. However, in this case, top glass plate or bus electrode acts as a cathode and bottom plate or address electrode acts as an anode. So the IR emission in this case is from cathode side when observed from top side, as in ICCD pictures of normal dielectric layer.

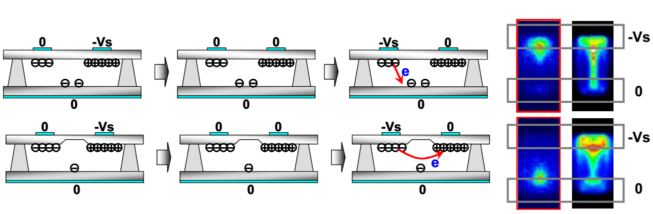

Fig. 2. ICCD image and wall charge diagram (Top: Vertical-triggering discharge mode, Bottom: Surface-only discharge mode)

This difference of discharge mode is important because it affects the uniformity of the panel while operating. Since the vertical-triggering discharge mode is initiated by a discharge between MgO layer and phosphor layer, the uniformity between cells with different phosphor (red, green or blue) is worse. As shown in Figure 3, with conventional dielectric layer discharge starting time and strength varies in red, green and blue cells. Phosphors have different electric characteristic, shape of the applied layer and grain size, and this difference caused non-uniform discharge in red, green and blue cells. With grooved dielectric layer, the discharge is not affected by phosphor layer so the uniformity of the panel was improved.

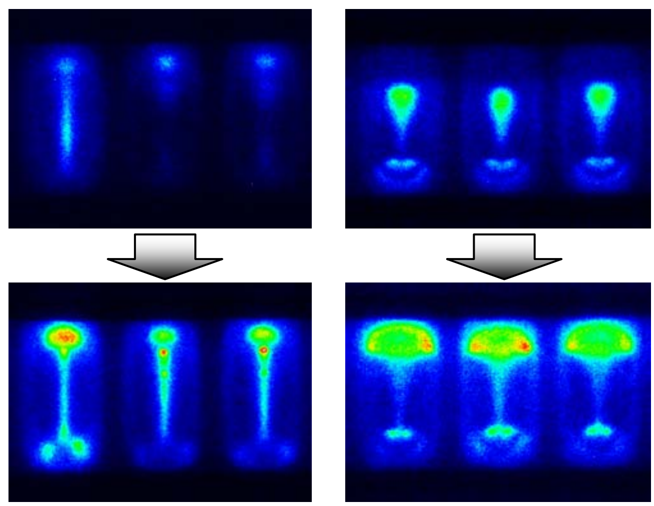

Fig. 3. ICCD image of discharge (Left: Conventional dielectric layer, Right: Grooved dielectric layer)

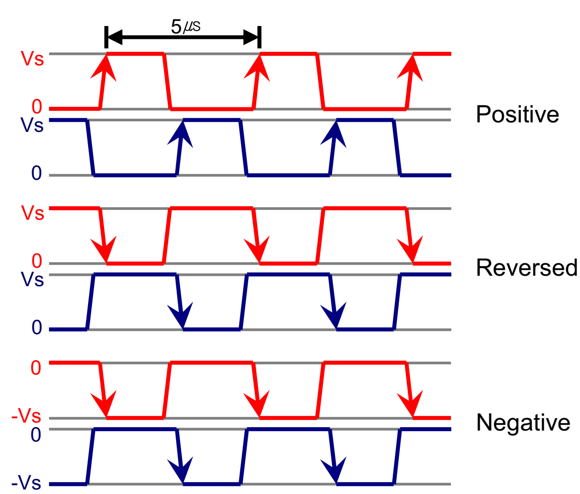

Fig. 4. Sustain waveform

In long discharge gap panel, the sustain voltage is high enough to create self-erase with normal positive sustain waveform, so a new sustain waveform was required. Figure 4 shows three different sustain waveforms. A negative-type sustain waveform and positive-reverse sustain waveform was used in this experiment, which applies negative-going pulse to initiate discharge instead of normal positive-going pulse. These new sustain waveform reduces self-erase discharge and enable us to operate long discharge gap panel with high sustain voltage.

Two-dimensional simulation was done to analyze the discharge characteristics and wall charge transition. Both negative sustain and positive-reverse sustain was simulated with conventional dielectric layer and grooved dielectric layer structure.

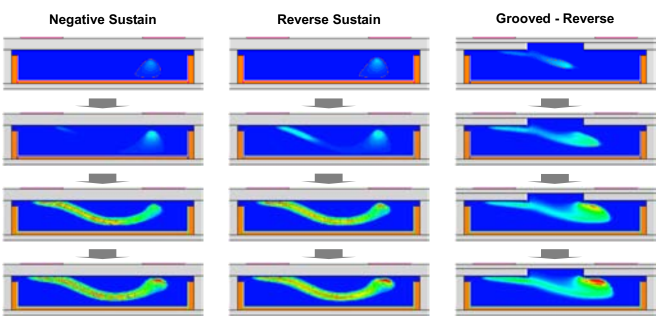

Fig. 5. Electron density profile (Left: Negative sustain, Middle: Positive-reverse sustain, Right: Negative sustain with grooved dielectric layer)

The electron density profile is shown in Figure 5. Figure 5 shows the electron density profile changing during the discharge process. With conventional dielectric layer, vertical discharge takes place first and transfer into surface discharge both in negative and positive-reverse sustain mode. With grooved dielectric layer structure, surface discharge takes place first and the discharge path is shorter. Also the discharge path is closer to top plate compared to conventional dielectric layer.

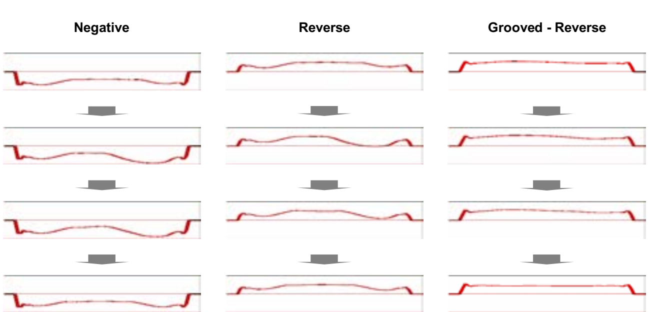

Fig. 6. Wall charge profile on bottom substrate (Left: Negative sustain, Middle: Positive-reverse sustain, Right: Negative sustain with grooved dielectric layer)

The wall charge profile on the bottom plate is shown in Figure 6. In conventional dielectric layer structure, the wall charge at the electrode with negative-going pulse applied is fluctuating due to vertical discharge. However, in grooved dielectric layer structure, the wall charge on the bottom plate does not change much.

Based on those 7.5” test panel results and simulation results, the design specification for 42” panels were determined. The depth of groove in dielectric area, material of the dielectric area (with varied relative permittivity), fabricating process and the position of bus electrodes have been investigated in 42” panels.

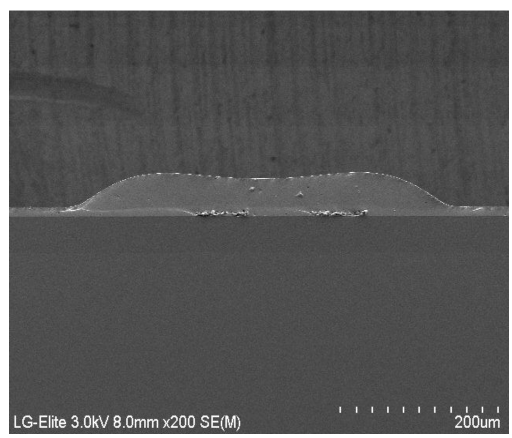

Fig. 7. SEM image of dielectric groove

Fig. 8. Picture of a 42” panel

In Figure 7, SEM image of the grooved dielectric layer structure is shown. Along with this grooved dielectric layer, all the high-efficacy design concepts such as new materials, new driving waveforms, optimized electrode positions and structures are applied to 42” panel and the luminous efficacy of this panel was 2.6lm/W. The picture in Figure 8 is image displayed on the final 42” panel with 2.6lm/W luminous efficacy.

4. Summary

A high-efficacy AC PDP design concept featuring long discharge gap with grooved dielectric layer has been proposed. The grooved dielectric layer enforces surface discharge so that the sustain voltage has been reduced and the uniformity of discharge has been improved. By controlling the shape of grooved dielectric layer, discharge current was decreased, which leads to improved efficacy. Based on these results, 42-inch panels were designed and fabricated. A new circuit board was designed, which could operate the panel with newly designed driving waveform featuring weak discharge reset and modified sustain waveform. By applying optimized combination of design factors mentioned above, luminous efficacy of 2.6lm/W has been achieved with 42-inch panel.

5. References

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