Effect of Aluminum Fence-type electrode Design on Characteristics of AC-PDP

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Abstract

In an attempt to enhance luminance efficiency and to reduce discharge delays of test panels with aluminum fence-electrodes, various designs of the electrodes were prepared by chemically etching the aluminum foils bonded to soda-lime glass substrate via anodic bonding process. The effects of fence design on luminance and discharge characteristics were investigated and compared with conventional ac-PDPs. These results showed a possibility of using fence-type aluminum electrode at front plates of ac-PDDs without sacrificing its performance.

1. Introduction

In our previous study [1], we have demonstrated that the use of Box-type aluminum fence-electrode on soda lime glass substrate may render characteristics of ac-PDPs similar to those of conventional ITO/Ag BUS electrode structure. This combination of aluminum electrode on soda lime glass substrate is expected to reduce material and production costs of ac-PDPs dramatically. For actual applications of the aluminum fence-electrode to ac-PDPs, however, electrode designs with better luminous efficiency and shorter discharge delays compared with the conventional Box-type fence-electrode must be developed.

Various designs of aluminum fence-electrodes studied in this investigation are shown in Table 1. Those new fence-electrode designs attempted were based on the ideas used in conventional ITO/Ag BUS electrode designs. Firstly, the concept of in-BUS structure proposed by Shinoda et al. [2] was utilized in designing the fence-electrode. They showed that the in-BUS structure is very effective in reducing firing voltages and in enhancing the efficacy, up to 5lm/watt. Thus, the fence-electrode morphology similar to the in-BUS design was attempted in the form of Box-type fence-electrode design. In the Box-type electrode, the width of fences at sustaining gap was increased to twice the width of rest of fence-electrode(20 μm).

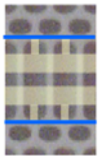
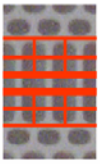
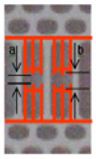
Although the in-BUS electrode improves the efficacy, the design may be prone to loss of space charges to the barrier ribs. In order to reduce the loss to walls, a electrode design similar to the T-shaped ITO electrode design[3] was attempted by segmenting the fence-electrodes, namely the Gate-type design in the Table 1. As the electrodes are segmented, it should reduce the loss of charged species to the walls as in the T-shaped or segmented ITO electrodes in ITO/Ag BUS electrode design.

Fence-electrode with igniters, i.e., Fork-type electrode, was attempted to utilize the igniter concept along with mid-gap sustaining structure proposed by previous studies[4]. Igniters near discharge gap were designed to initiate glow discharge at the igniter gap since the electric field should be higher at the tip of igniter. Manufacturing of the igniter tips using the typical Ag electrode materials has been very difficult since the sintering shrinkage during its firing process makes the control of igniter morphology very hard. In addition, the diameter of Ag powder is too coarse to produce fine shaped igniters of micrometer scale precision. The igniters prepared by etching of aluminum foil, on the other hand, could be processed with a high precision since it is manufactured by photolithography process.

Finally, L-type segmented fence-electrode was attempted to investigate the double gap effect on firing voltage and discharge delays.

Using such designs, fence-type sustain electrodes were prepared for test panels and their influences on discharge characteristics, luminous efficiency, and discharge delays were evaluated. The measured results were compared with test panels having conventional ITO/Ag BUS electrode structure.

Table 1. Geometry and cell opening ratio of fence-electrodes designed in this study.

Type	Reference	Box-type	Gate-type	Fork-type	L-type
Cell geometry					
Cell opening ratio	100%	75.6%	72.2%	74.5%	73.3%
Sustaining gap	70um	70um	70um	a : 70um b : 110um	a : 70um b : 180um

2. Experimental

Firstly, 6.5μm-thick aluminum foil was bonded directly onto a soda lime glass substrate via anodic bonding process. The aluminum foil was, then, coated with a photo resist and patterned in a form of fence-type electrode by chemical etching process. The electrode patterns formed were very uniform and top and bottom width of the etched fence-electrode was 10μm and 20μm, respectively. The fence-type electrodes were then covered with glass dielectric layer of 30μm thick. Subsequently, the glass dielectric layer was coated with MgO thin film using E-beam process. The front plate with fence-electrode design was sealed with a rear plate coated with green phosphor (Zn_2SiO_4: Mn) to prepare the test panel. The rear plate has rectangular discharge cells of HD resolution of 40-inch diagonal. The panel was filled with Ne-4%Xe discharge gas of 400 torr pressure. Fig. 1 shows the 2-inch test panel prepared in this study. Uniform emission of green lights over the surface of the panel was realized.

Fig. 1. 2-inch test panel during glow discharge.

The test panels were aged at 250V, 30 kHz for 3 hours prior to the measurements. The luminance, luminous efficiency, and firing voltage were measured with such test panels and the discharge behavior of the panels was examined using a ICCD camera at mid-margin sustain voltages.

In addition, the address discharge time lags were measured by applying wave form as shown in Fig. 2. The measurement was conducted over 1,000 times and Laue plot was obtained to estimate the discharge delays.

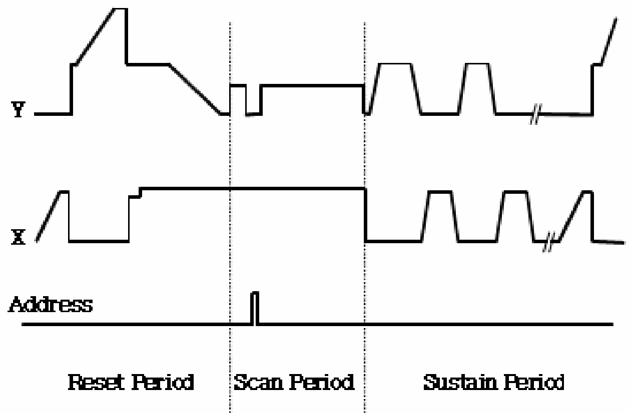


Fig. 2. Wave form of measuring the address discharge time lag.

3. Results and discussion

Table 2 summarizes static discharge voltages measured with test panels having different types of aluminum fence-electrodes. The firing voltage and static margin of the Gate-type electrode was enhanced 6% and 20%, respectively when compared with typical Box-type fence-electrode design. The segmentation of the fence-electrode in the Gate-type electrode might have played a role in reducing loss of charged spices and wall charge on the surface at the barrier ribs[5].

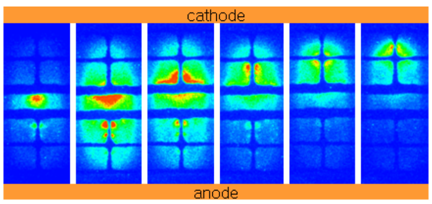
In case of Fork-type fence-electrodes with igniters at sustaining gap, glow discharge was observed to initiate at the gap(refer to Fig. 3(c)). As shown in Table 1, the firing voltages of the Fork-type fence-electrode was decreased significantly compared with conventional panel with ITO/Ag sustaining system. This indicates that with an appropriate design of fence-type electrode, discharge behavior of fence-type electrode may become similar to or superior to that of ITO/Ag Bus electrode.

The static margin was the highest with L-type, which has two different gaps between sustaining gap. The short sustaining gap should induce strong discharge and long sustaining gap could maintain weak discharge. This electrode design had a larger static margin, mainly due to increased firing voltages.

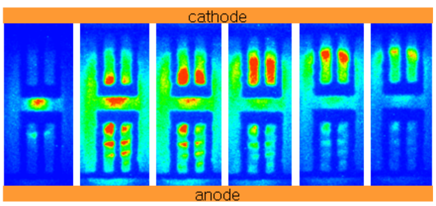
Table 2. Firing voltages of the test panels with different sustaining fence electrode design.

Type	First On	Last On	First Off	Last Off	Margin
Reference	201V	262V	178V	139V	23V
Box-type	242V	315V	225V	167V	17V
Gate-type	227V	283V	206V	157V	21V
Fork-type	188V	229V	167V	131V	21V
L-type	214V	242V	182V	154V	32V

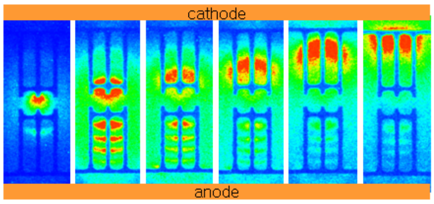
ICCD images of glow discharge with Box-type fence-electrode design revealed that an intense glow discharge propagates mainly along the surface of fences positioned along the center of discharge cells. Part of such discharge extended to the barrier ribs as shown in Fig. 3(a), leading loss of charged species at the rib surfaces. With the Gate-type electrode design, on the other hand, the glow discharge became confined mainly between the electrode fences as shown in Fig. 3(b). This confinement is expected to reduce the loss of charged species to the walls, eventually leading to improvements in luminous efficiency and discharge delays. With the Gate- and Fork-type fence-electrode designs, strong negative glow on cathode surface and striation on anode surface were formed (Fig. 3 (b-c)). In these designs, the glow discharge appears to be stronger near the gap due to concentration of electric field at the gap. Therefore, the increased area fraction of electrode near discharge gap may have decreased the firing voltages as in the in-BUS design.



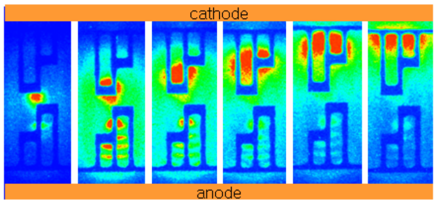
(a)



(b)



(c)



(d)

Fig. 3. ICCD images observed with (a) Box-type, (b) Gate-type, (c) Fork-type, and (d) L-type fence electrode design. The images were captured every 30ns after starting discharge.

Luminance of test panels with the fence-electrode designs was measured (Fig. 4). The luminance of the test panels with fence-electrodes was lower than that with conventional ITO/Ag BUS electrode structure, except the Fork-type fence-electrode design. It is believed that smaller foot area of fence-type electrode compared with ITO/Ag Bus electrode may be responsible for the reduced luminance. The luminance with Fork-type fence-electrode was higher, probably due to the strong discharge formed at the gap.

Luminous efficiency of such panels was measured (Fig. 5). It appeared that the luminous efficiency of fence-electrodes falls on a single curve, indicating the efficiency of glow discharge remains the same irrespective of the fence-electrode designs tested in this study. But the operation voltages of test panels were affected by the types of the fence-electrode design. This suggests that the design of fence-electrode is critical in determining the firing voltages of discharge cells.

Discharge time lags of the test panels with fence-electrodes were shown in a form of the Laue plot [6] in Fig. 6. Formative delay time of Fork-type electrode was the shortest, reflecting strongest electric field formed between the igniters at the sustaining gap. The statistical delay, which is the slope of the curves, was similar to that conventional ITO/Ag BUS electrode structure. The change in the fence-electrode design did not affect the statistical delay notably.

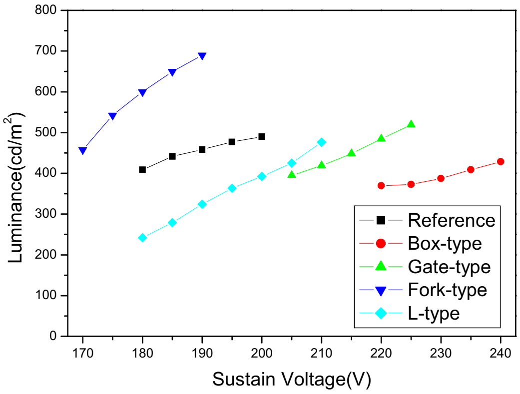


Fig. 4. Luminance of test panels with different fence-type designs.

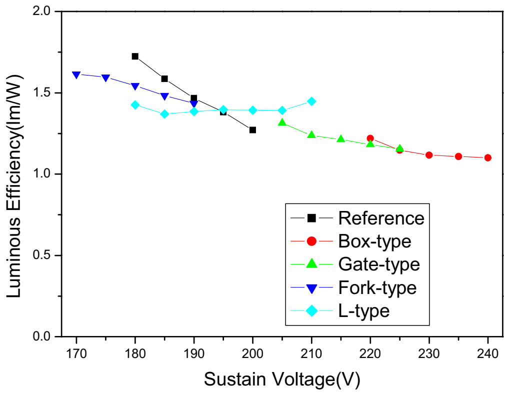


Fig. 5. Luminous Efficiency of test panels with different fence-type designs.

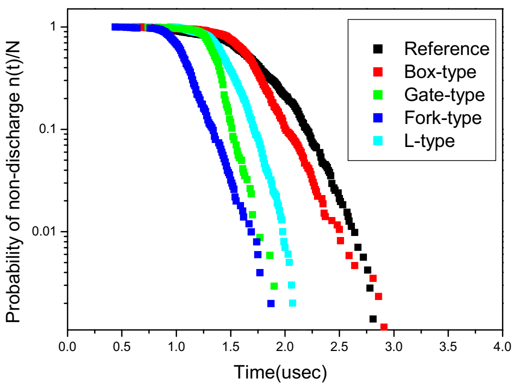


Fig. 6. Laue plot of glow discharges for different type electrodes

4. Summary

In this study, various aluminum fence-electrode designs were attempted by chemically etching the aluminum foil directly bonded to soda-lime glass substrate. The fence-electrode design includes Gate-, Fork-, and L-type electrode pattern. Among the designs, Fork-type fence-electrode showed superior ac-PDP performance compared with conventional ITO/Ag BUS electrode design. These results demonstrate a possibility of reducing the material cost of ac-PDPs by replacing ITO/BUS electrode with Aluminum fence-electrode without sacrificing the performance of ac-PDPs.

5. Acknowledgements

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6. References

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