Invited: High Efficacy AC-PDP toward 10 lm/W

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Abstract

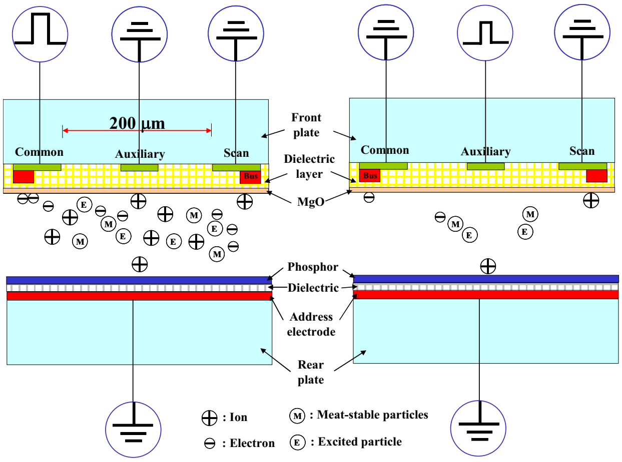
The high efficacy concept, featuring in this study an auxiliary electrode and a 200 μm coplanar gap, is applied to AC-PDPs with a stripe - type and a closed - type barrier rib, respectively. The roles of the pulses applied to the auxiliary electrode create additional excitation during the sustain period and reduce a discharge current that flows into the display cells. The efficacy of the proposed panel with the closed barrier rib has maximum values when the auxiliary pulse voltage is 50 volts and 80 volts for the Ne+4%Xe and Ne+20%Xe gas-mixtures, respectively. The maximum luminous efficacy is more than 10 lm/W in terms of the measurement of the discharges in VGA resolution (540 μm x 720 μm) and the green cells.

1. Introduction

Since AC - plasma display panel (PDP) was invented in 1964 by Bitzer and Slott at the University of Illinois, endless and enormous efforts to improve the characteristics of the original AC- PDP have been made. To date, AC-PDP has become one of the most brilliant technologies in the information display device field. The applications of AC- PDP to digital television screens and large-area commercial display panels are good examples of this. However, there are several problems that remain to be solved in order for this technology to compete with other information display device technologies. One of these issues has to do with the luminous efficacy. Compared to thin film transistor liquid crystal displays (TFT- LCD), and other emerging technologies, AC- PDPs have a relatively low luminous efficacy. This efficacy is somewhat related to power consumption. In general, the power consumption of a display device increases as the size of the panel increases. In particular, an AC-PDP consumes more power at a full white level [1]. Essentially, the mechanism of an AC- PDP is similar to a fluorescent lamp whose efficacy is approximately 80 lm/W. The luminous efficacy of a commercial product of an AC-PDP is about 1.5 ~ 2 lm/W. The question then arises of why an AC-PDP has a lower luminous efficacy compared to fluorescent lamp. The answer lies in the fact that a fluorescent lamp has a larger discharge gap and smaller stokes-shift characteristics in comparison with an AC- PDP. The discharge coplanar gap of an AC- PDP is a range of 60 ~ 100 μm. In the case of an AC- PDP with a tri-electrode structure using an Ne+5%Xe gas-mixture, 24% of the dissipated energy in the microplasma is used for exciting the xenon, and only 14% is used for generating the vacuum ultra violet (VUV) photons[2]. The stoke shift of the phosphor used in an AC- PDP is larger than that for a fluorescent lamp. In AC- PDP, phosphor must convert the photons with wavelength of 147 nm and 173 nm into visible photons. There are two types of possible approaches for AC- PDPs in terms of improving their luminous efficacy. First is to improve excitation rate of discharge gases by increasing the coplanar-gap [3, 4] and the high xenon content gas-mixture discharges [5]. The second is to reduce the stoke shift [6]. The latter approach is not dealt with in this work as the gas- mixture and phosphor are entirely different from conventionally used gas- mixtures and phosphors. High excitation gas discharges are focusing on in this work. It is necessary to determine method for improving the excitation rate of the microplasma in an AC- PDP in order to realize a high luminous efficacy. In this study, a coplanar- gap of 200 μm and an auxiliary electrode located between the scan and common electrode is proposed. The mechanisms of the proposed AC- PDP are discussed and the experimental results of the application of the proposed structure to the stripe and the closed barrier rib cells are shown later in this work.

2. New cell structure

The proposed cell structure is featured by a coplanar gap of 200 μm and an auxiliary electrode. Fig. 1 shows a schematic drawing of the proposed cell structure with the 200 µm coplanar gap and the auxiliary electrode. The gap between the scan and common electrode can vary in accordance with such factors as the gas- mixture ratio, the gas pressure, and the cell geometry. In this work, a 200 µm coplanar gap is used as referenced to a previous work [4]. The main roles of the auxiliary electrode are to improve the luminous efficacy during the sustain period, stabilize the reset discharge, and enhance the addressability. In this work, only improving the luminous efficacy as a role of the auxiliary electrode for during the sustain period is discussed.

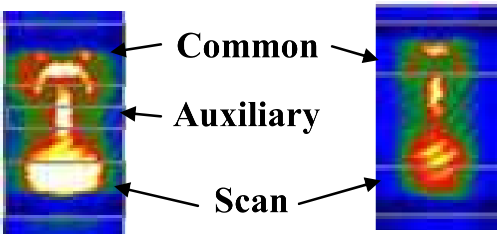


(a) During glow (b) During afterglow

Figure 1. Schematic drawing of the proposed cell structure and the operation (a) during glow and (b) during afterglow.

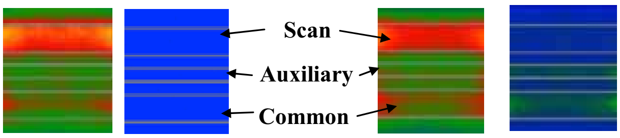
In general, the sustain discharges are repeated by periodic pulses which create a glow and an afterglow in turn. During the glow discharges, the space charges and the excited particles including meta-stable species are generated and decayed, and some of the space charges become wall charges on the dielectric layer. During the afterglow, a small number of the space charges and a quantity of the meta-stable particles including the excited species are still alive. In the proposed cell structure, the periodic pulses are applied to the auxiliary electrode after applying the sustain pulse. The existence of the auxiliary electrode and the applied pulse influence the distribution of the charged particles and excited particles during both the glow and afterglow.

Fig.2 shows a comparison of the infra-red (IR) emission characteristics between a case in which the pulse is applied to the auxiliary electrode and a case of non - auxiliary electrode. From the result, it is found that the role of the auxiliary electrode is to create a strong IR emission during the glow. In particular, the cathode region that includes the scan electrode has a stronger IR emission compared to the non - auxiliary electrode case with a coplanar gap of 200 µm. In addition, another strong IR emission around the auxiliary electrode is observable. Typically, compared to a shorter gap discharge, the long coplanar gap discharges have a higher excitation rate due to their relatively low electric fields. Moreover, the auxiliary electrode enhances the excitation rate of the microplasma generated in the 200 µm coplanar gap.



(a) (b)

Figure 2. Comparison of the IR emission characteristics between (a) a case in which a pulse is applied 50 V to the auxiliary electrode; and (b) a case of non-auxiliary electrode in a coplanar gap of 200 µm.



glow afterglow glow afterglow

(a) (b)

Figure 3. IR emission during afterglow when (a) the auxiliary electrode is grounded; and (b) a 50V pulse is applied to the auxiliary electrode.

Fig. 3 shows the IR emission during the afterglow when the auxiliary electrode is grounded and when a pulse of 50 V is applied to the auxiliary electrode. In the case of the grounded auxiliary electrode, there is no IR emission during the afterglow. However, a slight IR emission near the common and auxiliary electrode is observed when a pulse of 50 V is applied to the auxiliary electrode during the afterglow. This type of slight IR emission does not contribute to creating a discharge current. The pulse applied to the auxiliary electrode can indirectly influence the excited particles, leading to their activation during the afterglow; consequently, influence the next step periodic discharge. This result can be explained by a previous result in which a perturbation pulse during the afterglow was shown to influence the distribution of the excited and the meta-stable particles indirectly [7]. Therefore, it is clear that an additional role of the auxiliary electrode is to create prime particles during the afterglow.

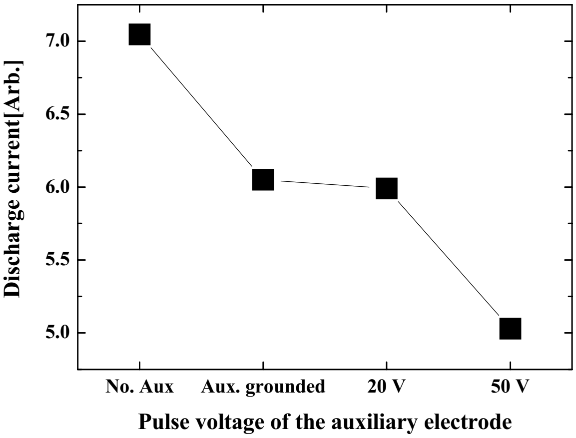
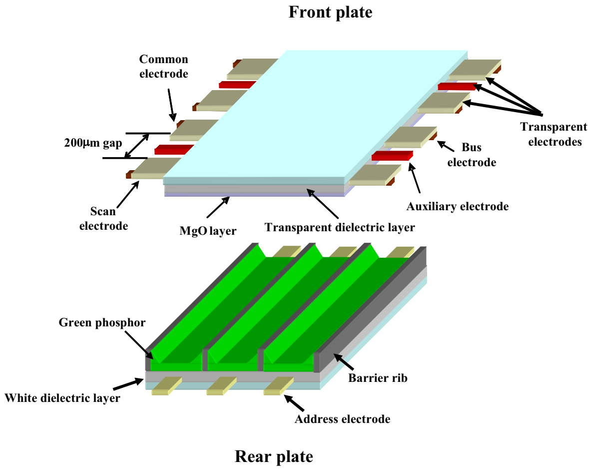


Figure 4. Discharge current in the display cells in accordance with the conditions of the auxiliary electrode.

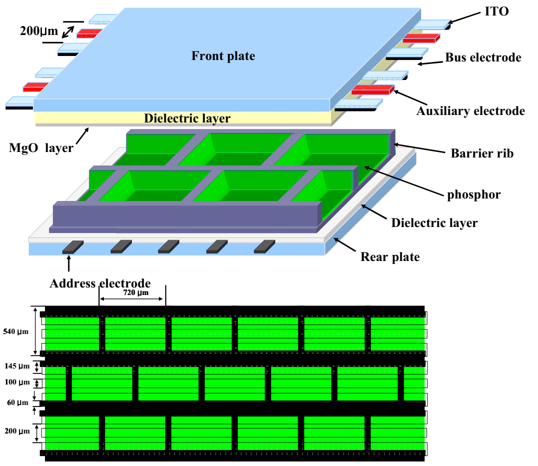
Fig.4 shows the discharge current in the display cells with and without the auxiliary electrode. As shown in Fig.4, the discharge current can be reduced as the pulses are applied to the auxiliary electrode. The existence of the auxiliary electrode between the scan and common electrode plays the role of reducing the discharge current flowing into the display cells. However, when the voltage of the pulse applied to the auxiliary electrode increases to over 100 V, the discharge current begins to increase rather than decrease. It is thought that discharges between auxiliary and sustain electrodes occur when a pulse is applied at greater than 100 V to the auxiliary electrode. It is clear that another important role of the auxiliary electrode is to reduce the current flowing into the display cells.

A summary of the roles of the auxiliary electrode is as follows; First, enhancing the IR emission during the glow; second, creating a small amount of excitation rather than ionization during the afterglow; third, reducing the discharge current. For these reasons, the pulses applied to the auxiliary electrode located between the scan and common electrode increase the excitation rate of the microplasma generated at the display cells of an AC- PDP with a coplanar gap of 200 μm. The proposed structure in this work is termed a "Fourth Electrode for enhancing the Excitation rate in a Long Coplanar gap (FEEL)" PDP.

3. Luminous Efficacy of FEEL PDP



(a) FEEL PDP with stripe barrier ribs



(b) FEEL PDP with the closed barrier ribs

Figure 5. Schematic drawings of the test panel adopting the new proposed structure.

Based on the proposed cell structure, three inch test panels were fabricated. As shown in Fig.5, two types of barrier rib were adopted to the new proposed FEEL PDP. The first is a stripe barrier rib type, as shown in Fig.5(a). The second is a closed barrier rib type, as shown in Fig.5(b). The resolution of the pixel of the test panel corresponds to an SD(Standard Definition) 42- inch PDP. The dimensions of the test panels are shown in Table 1. In this experiment, only green phosphor is coated inside the barrier rib. Therefore, the luminous efficacy shown in this work is caused by the green color rather than by the white. Ne+4%Xe, Ne+13%Xe, and Ne+20%Xe are used as the discharge gas mixtures and the total gas pressure inside the test panel is fixed at 450 Torr.

		The proposed test panel with stripe BR	The proposed test panel with the closed BR
Sub-pixel pitch		0.36 mm x 1.08 mm	0.54 mm x 0.72 mm
Coplanar gap		200 μm	200 μm
Width of sustain electrode		200 μm	145 μm
Width of aux. electrode		100 μm	100 μm
Height of BR		150 μm	150 μm
Dielectric layer	front	40 μm	40 μm
	rear	20 μm	20 μm

Table1. Dimensions of the test panels

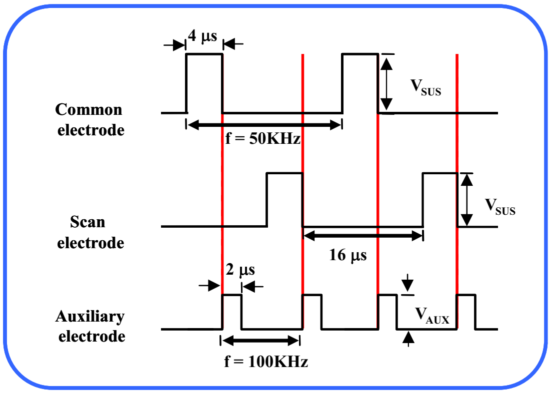


Figure 6. Pulse waveforms applied to the scan, common, and auxiliary electrode during the sustain period

Fig. 6 shows the pulse waveforms used to investigate the luminous efficacy. Periodic pulses are applied to the auxiliary electrode during the sustain period. As mentioned in the previous section, the pulses are applied to the auxiliary electrode during the afterglow directly following the sustain pulse. The width of sustain pulses is 4 μs and its frequency is 50 KHz. The width of the auxiliary pulse is 2 μs and its frequency is 100 KHz.

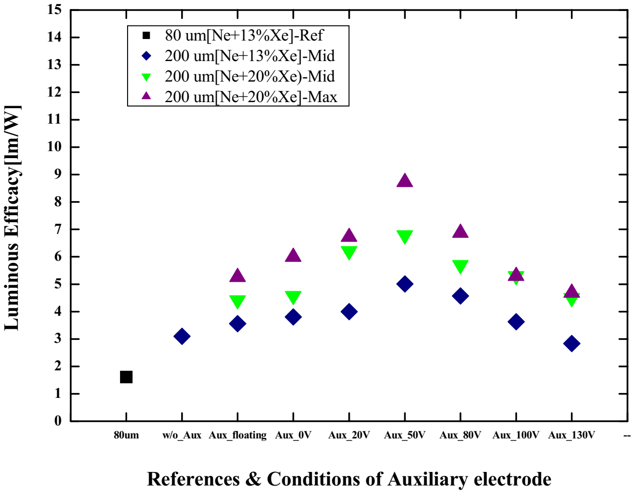


Figure 7. Luminous efficacy of the reference cells and the proposed structure when the stripe barrier ribs are adopted in accordance with the conditions of the auxiliary electrode

Fig.7 shows the luminous efficacy of the reference cells of the coplanar gap of 80 μm, coplanar gap of 200 μm without an auxiliary electrode, and the proposed structure with a coplanar gap of 200 μm and an auxiliary electrode for the adopting strip barrier rib. The reference cells of a coplanar gap of 80 μm show an efficacy of 1.6 lm/W obtained from the Ne+13%Xe gas- mixture discharges. When a Ne+13%Xe gas- mixture is used for the proposed test panel with strip barrier ribs, the luminous efficacy is greater than that of the cells without the auxiliary electrode. The efficacy has its maximum value when the voltage of the pulse applied to the auxiliary electrode is 50 V. Thereafter, the efficacy decreases. When a Ne+20%Xe gas- mixture is used as the discharge gas in the proposed test panel, a similar result to that of a Ne+13%Xe gas- mixture is observed. In this case, the maximum luminous efficacy is approximately 8.7 lm/W. In Figs.7 and 8, "Mid" indicates the luminous efficacy value at the mid-value of the sustain voltage margin, and “Max” is the luminous efficacy measured at the minimum sustain voltage.

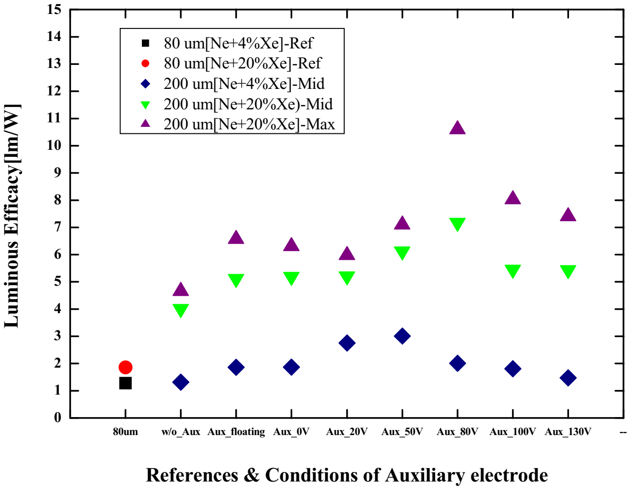


Figure 8. Luminous efficacy of the reference cells and the proposed structure using closed barrier ribs in accordance with the conditions of the auxiliary electrode

Fig.8 shows the luminous efficacy of the proposed panel with a closed barrier ribs in comparison with the reference cells. Here, the reference cell also has a closed barrier rib. The luminous efficacy of the Ne+4%Xe and Ne+20%Xe gas-mixture in the reference cells are 1.28 and 1.86 lm/W, respectively. When a Ne+4%Xe gas-mixture is used in the proposed panel, the luminous efficacy shows identical behavior as that of the proposed panel with stripe barrier ribs in accordance with the conditions of the auxiliary electrode. When a Ne+20%Xe gas- mixture is used in the proposed test panel with a closed barrier rib, the characteristics of luminous efficacy are slightly different from Ne+4%Xe in a closed barrier rib and Ne+20%Xe in a stripe barrier rib. The luminous efficacy has its maximum value when the voltage of the pulse applied to the auxiliary electrode is 80 V. The absolute value of the efficacy is slightly higher compared to that of the case with the stripe barrier rib. It is because that the loss to wall in the AC-PDP with a closed barrier rib is smaller compared to the AC-PDP with a stripe barrier rib [8].The maximum luminous efficacy is approximately 10.6 lm/W. As is clear from these results, a closed barrier rib is suggested for the proposed structure in order to get a high level of luminous efficacy when a high xenon content gas- mixture with neon is used as the discharge gas.

4. Conclusion

The luminous efficacy of an AC- PDP depends on the gas-mixture, cell geometry, and materials such as MgO and phosphor. In particular, the energy conversion loss of the microplasma in the display pixel represents the most important reason for the low efficacy of AC- PDPs. A conventional AC- PDP with a tri-electrode and a normal coplanar gap (60 ~ 100 μm) shows good display characteristics. However, the conventional AC- PDPs can not outperform any other display devices in terms of efficacy. A significant variation of the conventional structure should be made in order to realize a high level of luminous efficacy such as 10 lm/W. In this work, the coplanar gap is widened from 80 μm to 200 μm and an auxiliary electrode is inserted between the scan and common electrodes. A role of the auxiliary electrode is to enhance the IR emission during the glow, providing prime particles during afterglow; in addition, its role is to reduce the discharge current. Test panels adopting high efficacy concepts were fabricated, featuring a coplanar gap of 200 μm and an auxiliary electrode. Two types of barrier rib, a stripe barrier rib and a closed- type barrier rib were used. As in the previous results, the pulses applied to the auxiliary electrode enhance the luminous efficacy. When a Ne+13%Xe and a Ne+20%Xe gas- mixture are used for the proposed panel with the stripe barrier rib, the maximum value of the luminous efficacy is obtained at an auxiliary pulse voltage of 50 V. When a Ne+13%Xe gas- mixture is used for the proposed panel with the closed barrier rib, the characteristics of the luminous efficacy in accordance with the conditions of the auxiliary electrode are nearly identical to those of the case with the stripe barrier rib. When a Ne+20%Xe gas- mixture is used for the proposed panel with the closed barrier rib, the maximum luminous efficacy is 10.5 lm/W at an auxiliary pulse voltage of 80 V. This is obtained from the green cells. The high efficacy concepts proposed in this work are not completed, yet. The issues related to the fabrication and the driving of the proposed panel should be considered in further study. However, it is possible to obtain a high luminous efficacy of greater than 10 lm/W (green cells) using a coplanar-gap of 200 μm and an auxiliary electrode. Further research is needed in this area in order to realize a commercial product with a high level of luminous efficacy.

5. References

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