Analysis of micro-discharge with long discharge path in AC-PDP based on ICCD observation

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Abstract

The micro-discharge characteristics of an ac-PDP with a long discharge path (400μm) are analyzed based on ICCD observation at three different driving conditions. The ICCD observation indicates that the application of the address pulse at the discharge initiation plays a significant role in the initiation of the trigger discharge, the propagation of the long gap discharge from the trigger discharge to the main discharge along the address electrode, and the duration of the main discharge between the large sustain gaps.

1. Introduction

It is well known that if the discharge path becomes longer, the luminous efficiency will be improved [1]. Over the past few years, a considerable number of studies have been tried to lengthen the sustain gap for producing the discharge in the long discharge path of a PDP cell [2, 3, 4, 5]. In such a cell structure with a long discharge path, the main discharge between the two sustain electrodes cannot be produced directly because the distance between the two sustain electrodes is longer than that between the sustain and address electrodes. For the efficient long gap discharge, the discharge pathway should be satisfied as follows, as reported by L. Weber [2]: prior to the man discharge, the trigger discharge should be initiated between one of the sustain electrodes and the address electrode, extending toward the other

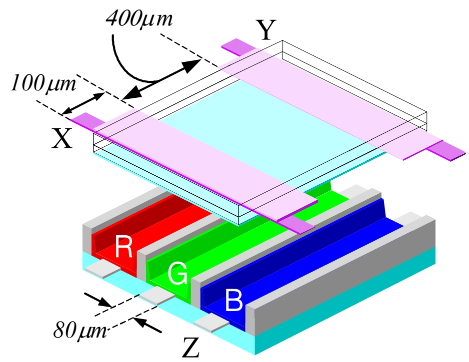


Fig. 1. Discharge cell structure employed in this experiment (sustain gap = 400 μm)

sustain electrode along the address electrode, and finally producing the main discharge. Further, it has been reported that, the inverted-like sustain waveform is necessary for sustaining this long discharge mode, meaning that two sustain pulses must be overlapped each other. Nonetheless, the sustain voltage is still high even in this discharge pathway suitable for the long discharge path. Our previous result showed that despite the same discharge pathway as that reported by L. Weber, the discharge characteristics, such as a minimum sustain voltage, luminance, and luminous efficiency, can be varied depending on the voltage distributions among the three electrodes [5]. In particular, the proper application of the address pulse to the address electrode can lower the minimum sustain voltage, thereby resulting in improving the luminous efficiency. Accordingly, the characteristics of the micro-discharge produced in the long discharge path needs to be analyzed in detail so as to lower the sustain voltage based on the voltage distributions.

In this paper, the discharge characteristics of an ac-PDP with a long discharge path are investigated by controlling the voltage distributions among the three electrodes. In particular, the discharge characteristics are examined with the variations in the width and amplitude of the sustain voltage and the amplitude of the address voltage, in detail.

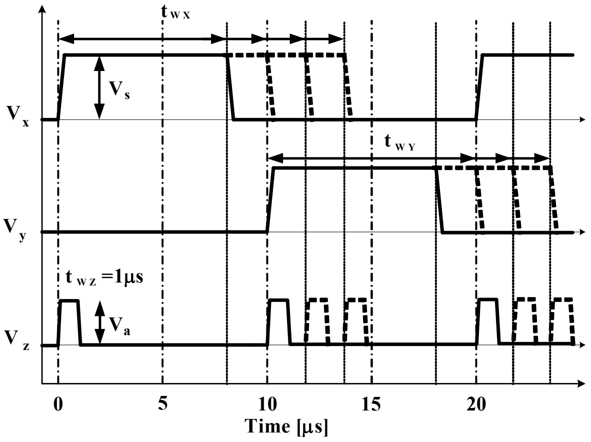


Fig. 2. Sustain voltage waveforms applied to three electrodes during sustain-period

2. Experiments

Fig. 1 shows the discharge cell structure employed in this experiment where the sustain gap is 400 µm, the sustain electrode (X or Y) width is 100 µm, the address electrode (Z) is 80 µm, and the height of the barrier rib is 125 µm. The R, G, and B phosphor layers are deposited between the ribs on the rear panel. The gas pressure is 500 Torr and the gas mixture is Ne-Xe (5 %). Fig. 2 shows the voltage waveforms Vx, Vy, and Vz applied to the sustain electrodes, X and Y, and address electrode, Z, respectively. Vx and Vy were applied alternately at a frequency of 50 kHz. The width of the sustain pulse (t_{WS} = t_{WX} = t_{WY}) is varied from 8 µs to 14 µs at intervals of 2 µs. At the t_{WS} of 8 µs, the two sustain pulses are apart, whereas at the t_{WS} greater than 8 µs, the two sustain pulses are overlapped each other, as shown in Fig. 2. The address pulse has the width of 1 µs, which is optimized experimentally [5]. The position of the address pulse is determined as follows: at the t_{WS} of 8 µs, it is coincided with a rising point of the sustain pulse, whereas at the t_{WS} greater than 8 µs, it is coincided with a falling point of the sustain pulse.

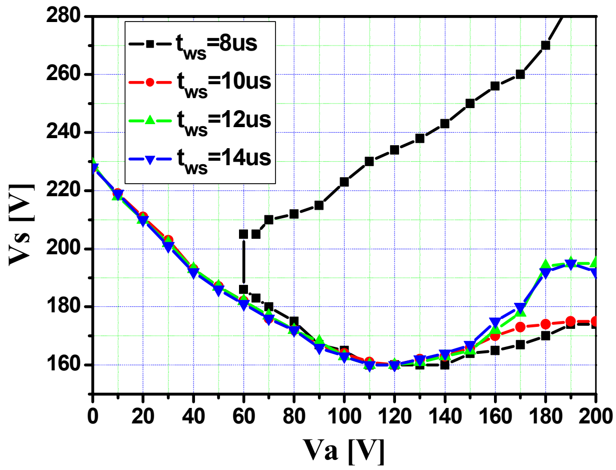


Fig. 3. Operational regions with variations in V_s and V_a at various T_{WS} and constant address pulse width of 1 µs.

3. Results and Discussion

3.1 Operational Region

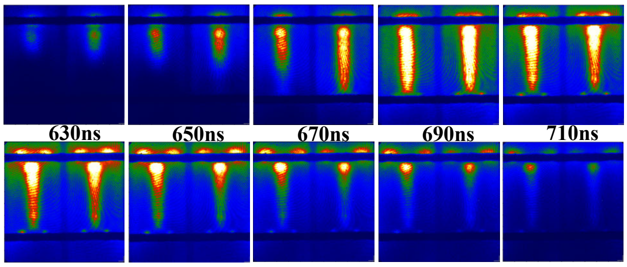
Fig. 3 shows the operational region that can determine the static voltage margin when the width, t_{WS} and the amplitude, V_s of the sustain pulse, V_x (or V_y), and the amplitude, V_a of the address short pulse, V_Z having a width of 1 µs, are varied. In the figure, each line means a boundary of operational region with the variation of t_{WS}. When V_a was zero, the discharge was sustained at V_s of 230V only if the sustain pulses were overlapped. However, when the V_a was applied, the discharge was sustained irrespective of the overlapping of the sustain pulses. In addition, as the Va increased, the discharge could be sustained at lower voltage level. Finally, the discharge was sufficiently sustained even at about 160 V to 170 V in the case of applying the address pulse with amplitude greater than 70V. It is remarkable that the presence of the address voltage at the initiation of the discharge can produce the long gap discharge even when the two sustain pulses are not overlapped, even though the operational region shrinks, as shown at the t_{WS} of 8 µs in Fig. 3. In this case, the positive address pulse can induce an efficient trigger discharge between the sustain and address electrodes because it satisfies the MgO cathode condition at the initiation of the trigger discharge. It is also remarkable that the presence of the address voltage at the initiation of the discharge can produce the long gap discharge even at a low sustain voltage irrespective of the overlapping of the sustain pulses. At the t_{WS} greater than 8 µs, when the duration of an overlapped time of the sustain pulses increased (*i.e.* t_{WS} increased from 10 µs to 12 µs or 14 µs), the operational region remained almost constant, as shown in Fig.3. Furthermore, it was observed the luminance and luminous efficiency in the overlapped sustain waveform had the same levels irrespective of the changes in the duration of an overlapped time (not shown here).

3.2 ICCD Observation

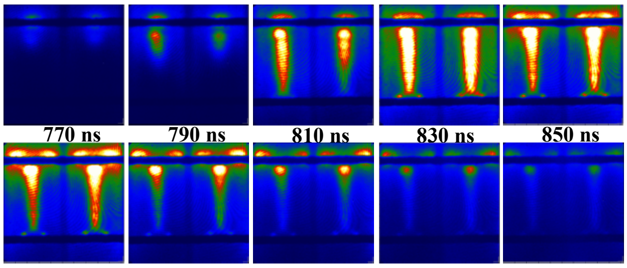
Figs. 4 (a), (b), and (c) illustrate the temporal behavior of the IR emission images of the long gap discharge measured using the gate mode (exposure time: 20 ns) of the image-intensified charge-coupled device (ICCD) camera. The ICCD images in Fig. 4 were measured under three different driving conditions: case A, case B, and case C. In case A, the address pulse of 90V was applied when the applied 7two sustain pulses of 170V were not overlapped, whereas in case B, the address pulse of 90V was applied when the applied two sustain pulses of 170V were overlapped. In case C, the overlapped two sustain pulses of 230V were applied when no address pulse was applied. In all cases, A, B, and C, it was observed that the trigger discharge was initiated between the sustain and address electrodes, and the main discharge between the two sustain electrodes showed the narrow shape propagating along the address electrode. The measured ICCD images showed that the initiation of the trigger discharge was the fastest in case A (at 630 ns), and faster in case B than case C, among the three cases. This phenomenon shows that the address pulse helps a trigger discharge process, indicating that the trigger discharge can be induced more easily and quickly, when the address pulse is applied. The propagation of the long gap discharge from the trigger discharge to the main discharge along the address electrode was also observed to be the slower in cases A and B (about 40ns) than in case C (about 20ns). This result implies that the application of the address pulse in the long gap discharge plays a significant role in controlling the propagation speed of the long gap discharge from the trigger discharge to the main discharge along the address electrode. Moreover, the durations of the main discharge between the X and Y electrodes were for 40 ns in both the cases A and B, whereas in case C, it was shorter (20 ns) than in cases A or B. This result shows that the duration of the main long gap discharge can be varied depending on the application of the address pulse, which can affect the luminous efficiency of the long gap discharge.

3.3 Current Waveform and IR intensity

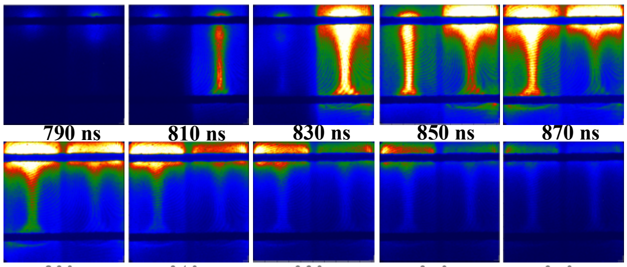
Fig. 5 shows the discharge current (except the displacement current) and IR waveforms measured from the test panel when applying the same driving waveforms in cases A, B, and C of Fig. 4. The current data of Fig. 5 confirm that the initiation order of the trigger discharge



(a) Case A : $V_s = 170$ V, $V_a = 90$ V and $t_{WS} = 8$ μs



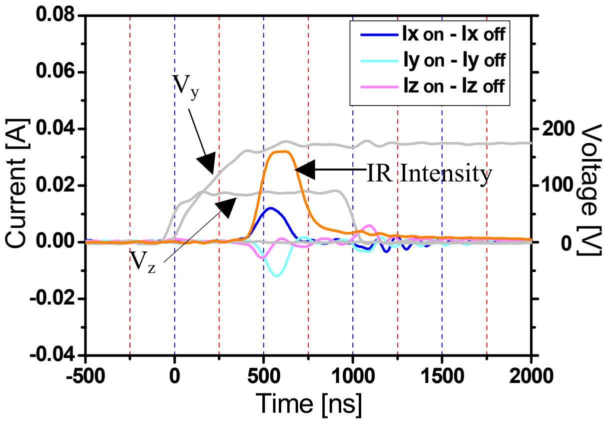
(b) Case B : $V_s = 170$ V, $V_a = 90$ V and $t_{WS} = 10$ μs



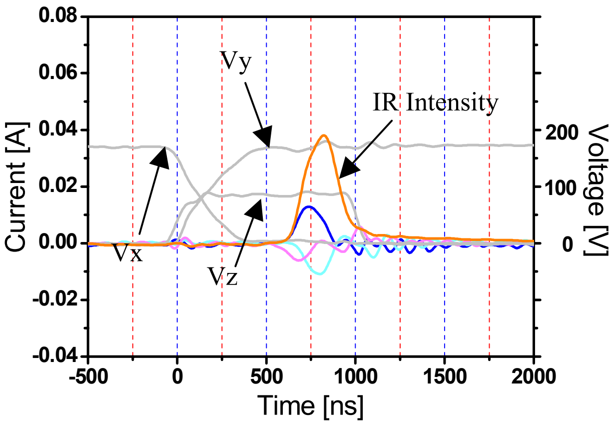
(c) Case C : $V_s = 235$ V, $V_a = 0$ V and $t_{WS} = 10$ μs

Fig. 4. ICCD images of long gap discharges measured using gate mode at three different driving conditions.

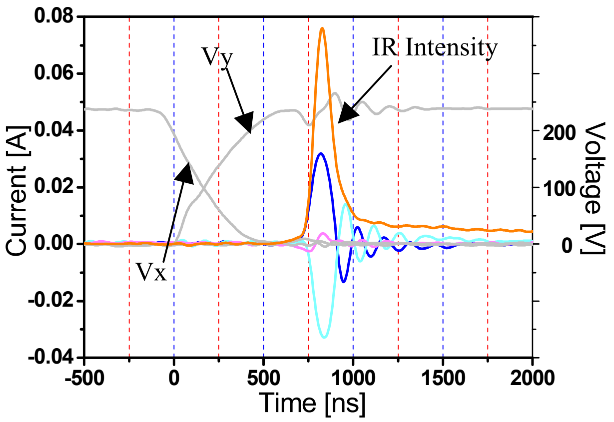
is case A, case B and case C. The current waveforms in cases A and B show the same duration of the main discharge, which is longer than that of the main discharge in case C. As a result, the cases A and B show the longer IR emission characteristics than case C, as shown in the IR waveforms of Fig. 5. These results are well matched with those of the ICCD images in Fig. 4. The measured current data also showed that the duration of the discharge current flowing through the X and A electrodes was longer in cases A and B than in case C. In addition, the ratio of the discharge current I_x to I_z was lower in cases A and B in case C, indicating that the amount of the discharge current flowing through the address electrode in cases A and B were large. In cases A and B, the polarities of the discharge currents flowing through the address electrodes were not changed during the main X-Y discharge, whereas in case C, the polarity of the discharge current flowing through the address electrode was changed during the main X-Y discharge.



(a) Case A : Vs = 170 V, Va = 90V and t_{WS} = 8 μs



(b) Case B : Vs = 170 V, Va = 90V and t_{WS} = 10 μs



(C) Case C : Vs = 235 V, Va = 0V and t_{WS} = 10 μs

Fig. 5. Current and IR emission under the voltage driving condition of Fig. 4

3.4 Luminance and Luminous Efficiency

Fig. 6 shows the changes in the luminance and luminous efficiency at different driving conditions such as cases A, B and C. The higher sustain voltage condition in case C showed the highest luminance, but the lowest luminous efficiency. Even though the cases A and B had the same sustain and address voltage condition, the discharge characteristics were a little different as follows: the luminance in case B was a little higher, whereas the luminous efficiency in case A (the sustain pulses were not overlapped) was much higher.

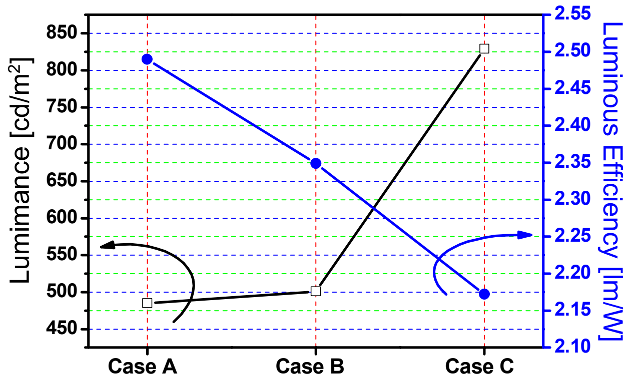


Fig. 6. Luminance and the luminous efficiency under three different driving conditions of Fig. 4

Conclusion

The micro-discharge characteristics of an ac-PDP with a long discharge path (400μm) are analyzed based on ICCD observation at three different driving conditions. The ICCD observation indicates that the application of the address pulse at the discharge initiation plays a significant role in the initiation of the trigger discharge, the propagation of the long gap discharge from the trigger discharge to the main discharge along the address electrode, and the duration of the main discharge between the large sustain gaps.

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