P-70: New Long Gap Discharge Mode Driven by Low Sustain Voltage for Highly Efficient Plasma Displays

Hyun Kim, Jae Young Kim, Heung-Sik Tae

School of Electronic and Electrical Engineering, Kyungpook National University,

1370 Sankyuk-Dong, Buk-Gu, Daegu, 702-701, Korea

Jeong Hyun Seo

Electronics Engineering, University of Incheon, Inchon, 402-749, Korea

Seok-Hyun Lee

School of Electrical Engineering, Inha University, Inchon, 402-751, Korea

Abstract

This paper proposes a new long gap discharge mode with a long gap of 400 μm driven by a low sustain voltage (< 200 V) for a highly efficient three-electrode alternate current plasma display panel (ac-PDP). Two different types of long-gap discharge modes can be created depending on the voltage distribution among the three electrodes: a forward long gap discharge mode (FLGDM) with a high sustain voltage where the discharge is initiated from the voltage-supplied electrode, and a reverse long gap discharge mode (RLGDM) with a low sustain voltage where the discharge is initiated from the ground electrode. As such, in the current study, a highly efficient discharge mode in a long gap was efficiently constructed under a low sustain voltage by properly controlling the amplitude and width of the auxiliary short pulse applied to the address electrode, resulting in a reverse long gap discharge mode with a high efficiency of 2.5 lm/W at a sustain voltage of 170 V.

I. Introduction

For the realization of high quality plasma display devices, further improvements are needed as regards their low luminous efficiency [1, 2], which is inherently due to the use of the negative glow region produced by the short discharge gap (60~ 120 μm) of the conventional PDP cell structure. However, if the discharge gap becomes longer, the luminous efficiency will improve, since the weak electric field generated in the longer discharge gap produces an efficient discharge. However, the firing and sustaining voltages required to produce a discharge increase in

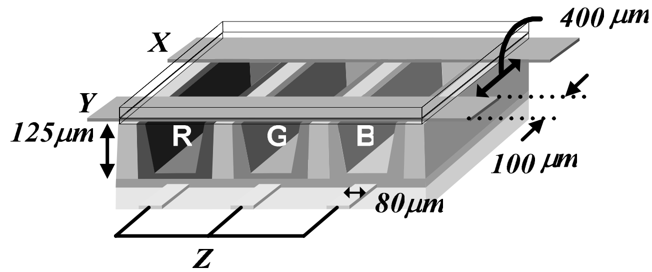

Fig. 1 Three-electrode micro-discharge cell structure and specifications of 7-inch test panel used in current study.

proportion to the length of the long discharge gap. Therefore, despite a long gap discharge, the high operating voltage can aggravate the luminous efficiency, as it causes a very high electron temperature. Furthermore, the high firing and sustaining voltages in a longer gap structure need to be lowered, usually by the addition of an auxiliary electrode between the two sustain electrodes with a long gap, for the stable driving of current PDP devices [3, 4]. However, under the current three-electrode PDP structure, the use of an address electrode is preferred to produce a long gap discharge, rather than an additional auxiliary electrode, so as to minimize the side effect of the direct discharge between two sustain electrodes with a long gap. According to a previous report by Weber on a long gap discharge when using an address electrode [5], the initial discharge or triggering discharge begins to be produced between the sustain and address electrodes prior to the main discharge between the two sustain electrodes, as the distance between the two sustain electrodes is too long. Then, the discharge

 ISSN/0004-0966X/04/3501-0510-$1.00+.00

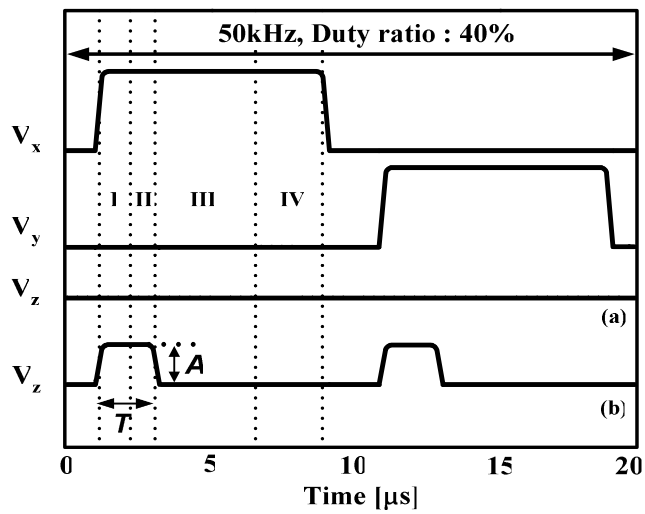

Fig. 2 Voltage waveforms applied to three electrodes to produce forward long gap discharge (FLGDM) (a) and reverse long gap discharge (RLGDM) (b).

extends along the address electrode toward the other sustain electrode, resulting in the main discharge between the two sustain electrodes with a long gap. However, in the long gap discharge proposed by Weber, the triggering discharge intensity can not be properly controlled because the potential difference between the sustain and address electrodes that produce the triggering discharge is constant. In a long gap structure, the triggering discharge intensity is an important parameter for a higher luminous efficiency. In addition, the firing and sustaining voltages are higher than those in a conventional short gap structure, because the wall charges accumulating on the address electrode can not be controlled efficiently, irrespective of the use of an address electrode. Consequently, the ability to control the wall charges accumulated on the address electrode is very important for a low sustain voltage in a long gap structure.

Accordingly, this paper proposes a highly efficient long gap (400 μm) discharge mode driven by a low sustaining voltage (<200V) based on controlling the voltage distribution among the three electrodes in a long gap AC PDP. In particular, the proper application of a short pulse to the address electrode during the supply of the sustain pulse is used to control the polarity and amount of wall charges accumulated on the address electrode per single sustain pulse, as well as the triggering discharge intensity.

II. Experiment

A 7-inch test panel filled with a gas mixture of Ne-Xe (5 %) at a pressure of 500 Torr was used in the current study, and a schematic diagram of a single pixel is shown in Fig. 1. The discharge gap between the two sustain electrodes, X and Y, was fixed at 400 μm, plus X and Y were covered with glass-based dielectric materials with a thickness of 38 μm. The thickness of the MgO layer was 5000Å , and the height of the closed-type barrier rib was 125 μm. Meanwhile, the width of the sustain electrodes, X or Y, was 100 μm, and the width of the address electrode (Z) was fixed at 80 μm. The dielectric layer covering the entire address electrode, Z, was 20 μm thick. The red, green, and blue phosphor layers were $(Y,Gd)BO_3:Eu$, $(Zn,Mn)_2SIO_4$, and $(Ba,Eu)MgAl_{10}O_{17}$, respectively. Fig. 2 shows the voltage waveforms V_x, V_y, and V_z applied to the sustain electrodes, X and Y, and address electrode, Z, respectively. V_x and V_y with a duty ratio of 40 % were applied alternately at a frequency of 50 kHz. No voltage was applied to the address electrode Z to produce the forward long gap discharge (FLGDM), as shown in Fig. 2 (a). Whereas, for the reverse long gap discharge(RLGDM), V_z was synchronized with the application of V_x and V_y, as shown in Fig. 2 (b). The amplitude(A) and width(T) of V_z in Fig. 2 (b) were varied to control the polarity and amount of wall charges accumulated on the address electrode per single sustain pulse, as well as the triggering discharge intensity.

III. Result and Discussion

Fig. 3 presents the simulated results of the time resolved electron density contours showing the firing process of the two different discharge modes due to the voltage distribution among the three electrodes. Fig. 3 (a) shows the forward long gap discharge mode (FLGDM) where the discharge was initiated from the voltage-supplied electrode, X. In this mode, 700V was applied to X, thus the voltage difference between X and Y and between X and Z was 700V. Since the distance between X and Z electrode

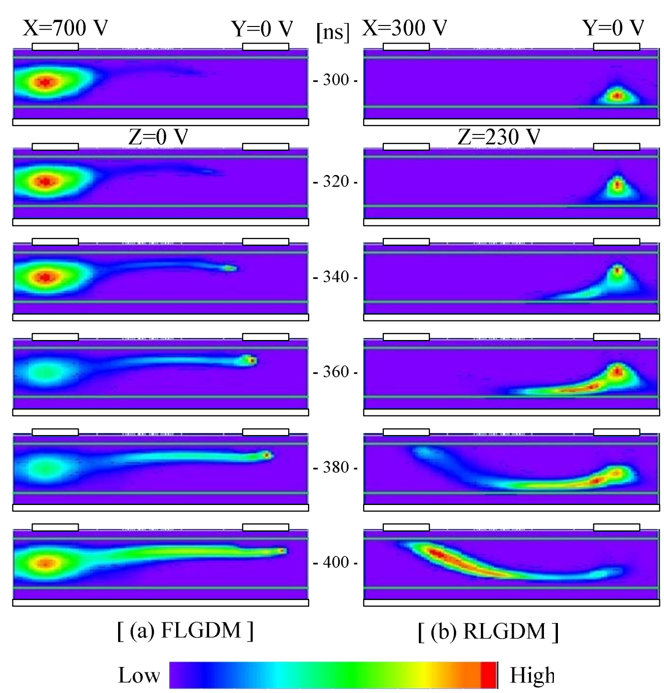

Fig. 3 Time resolved electron density contours of FLGDM (a) and RLGDM (b).

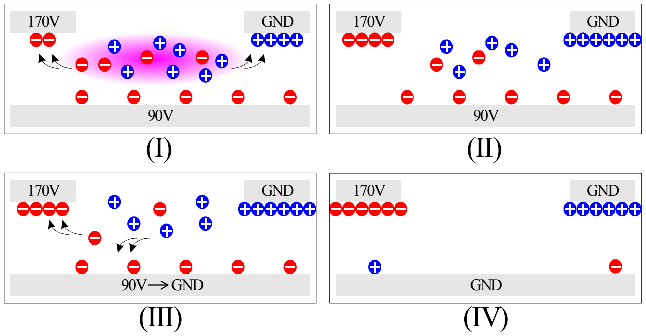

Fig. 4 Temporal behavior of wall charges within cell when RLGDM was produced by voltage waveforms in Fig. 2 (b).

was smaller than that between X and Y, the discharge was initiated between X and Z, and since the sustain electrode X with an MgO surface worked as an anode, the discharge ignition in this case required a high breakdown voltage. In addition, since the address electrode Z worked as a cathode, no electrons were accumulated along the address electrode Z, indicating that there was no transition of the X-Z discharge into the main long gap discharge. Thus, since the firing voltage in the FLGDM was relatively high, the discharge efficiency in the FLGDM was very poor, irrespective of the long gap structure, as most of the input power was consumed to produce the discharge between X and Z with very high electron temperature. Conversely, Fig. 3 (b) shows the reverse long gap discharge mode (RLGDM) where the discharge was initiated from the ground electrode Y. In the RLGDM, 300V and 230V were applied to X and Z, respectively. The discharge was then triggered between Y and Z due to the voltage difference between Y and Z (i: trigger), and extended along the address electrode (ii: extension) by charging the electrons along the address electrode. Finally, the discharge was connected to electrode X (iii: main discharge). In this mode, since the sustain electrode Y worked as a cathode, the ions were attracted to the MgO layer covering the dielectric in electrode Y. Thus, due to the effect of the very high gamma coefficient of MgO on the ions, the bombardment of ions enabled the main discharge to be produced between X and Y at a lower firing voltage than that in the FLGDM. Furthermore, since the address electrode Z worked as an anode, electrons were accumulated along the address electrode Z, indicating an efficient transition of the triggering discharge into the main long gap discharge. Therefore, the simulation results illustrated that the two different discharge modes (FLGDM & RLGDM) strongly depended on the voltage distribution among the three electrodes in a long gap structure: the FLGDM was set up when the voltage applied to the sustain electrode X was greater than two times the voltage applied to the address electrode Z ($V_x>2V_z$), whereas the RLGDM was set up when the voltage applied to the sustain electrode X was less than two times the voltage applied to the address electrode Z ($V_x \leq 2V_z$). This set-up condition could also be

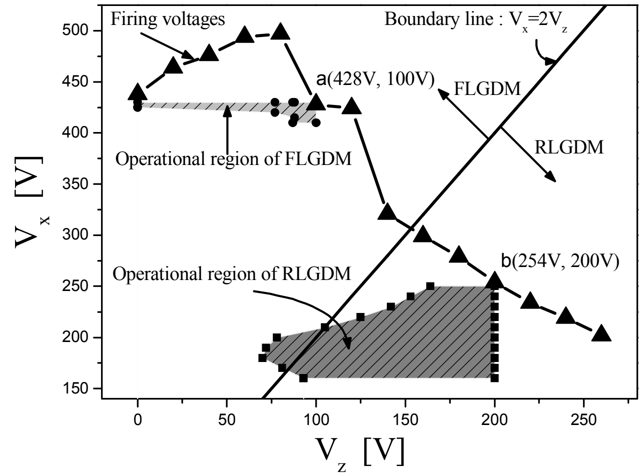

Fig. 5 Experimental results of firing and sustaining voltages relative to voltage applied to three electrodes at V_z with width of 1μs.

changed depending on the quality of the MgO surface. Two other factors should also be seriously considered to obtain a highly efficient RLGDM: the first is lowering the triggering discharge intensity between Y and Z, while the other is eliminating the accumulated electrons or changing the polarity of the electrons accumulated on the address electrode Z prior to the application of the subsequent sustain pulse. As such, when the RLGDM was produced by the voltage waveforms in Fig. 2 (b), the temporal behavior of the wall charges within the cell was shown in Fig. 4. In Fig. 2, the RLGDM was produced when a V_x of 170 V and V_z of 90 V were applied to the sustain and address electrodes X and Z, respectively. Then, during the long gap discharge, as shown in (I) and (II) in Fig. 4, electrons were accumulated on the sustain and address electrodes X and Z, whereas ions were accumulated on the grounded electrode Y. Then, when the voltage applied to the address electrode Z was changed abruptly from 90V to 0V, additional electrons and ions were accumulated from the remaining space charges on the sustain and address electrodes X and Z, respectively, due to the potential difference between X and Z, as shown in (III) in Fig. 4. The pulse width of V_z needed to be optimally controlled for the maximal accumulation of wall charges from the remaining space charges. As shown in (IV) in Fig. 4, the resultant wall charge distributions prior to the application of the next sustain pulse V_y enabled weak triggering discharge intensity between X and Z with low applied voltage on Z, and also promoted the accumulation of electrons along the address electrode, thereby resulting in a highly efficient long gap discharge driven by a low sustain voltage. Fig. 5 shows the experimental results for the firing and sustaining voltages relative to the voltage applied to the three electrodes with V_x=2V_z as the boundary line of the discharge mode and a discharge gap of 400μm. For the FLGDM, the measured firing voltage was over 300V. The operation region of the

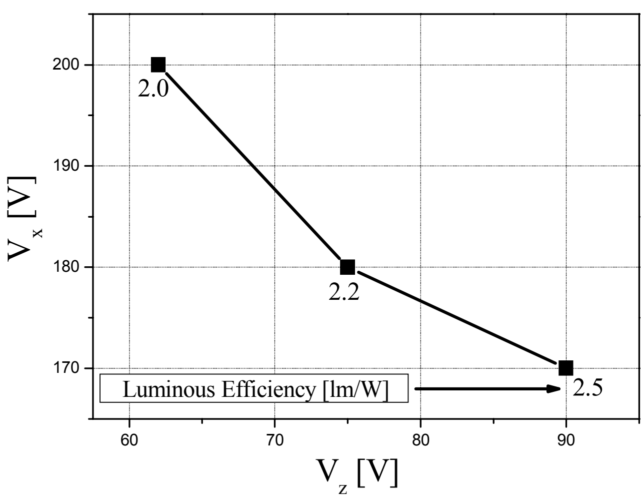

Fig. 6 Change in luminous efficiency with various V_x and V_z in RLGDM.

FLGDM, *i.e.*, sustaining region, was very slim and its sustain voltage very high when the FLGDM was produced at V_x=428V and V_z=100V ("a" in Fig.5). Meanwhile, for the RLGDM, the measured firing voltage was below 300V, and when the initial discharge was produced at V_x=254V and V_z=200V ("b" in Fig.5), the corresponding operation region, *i.e.*, sustaining region, was relatively large and its sustain voltage comparatively low, when compared with those for the FLGDM. The low sustain voltage in the RLGDM means the production of a highly efficient long gap discharge mode. As shown in Fig. 6, a higher luminous efficiency of 2.5 lm/W was obtained at a low sustain voltage of 170V by applying a short pulse with an amplitude of 90V and width of 1µs to the address electrode.

IV. Summary

A highly efficient reverse long gap discharge mode in a long gap can be effectively constructed under a low sustain voltage by properly controlling the amplitude and width of the auxiliary short pulse applied to the address electrode. As such, a reverse long gap discharge mode with a high efficiency of 2.5 lm/W was obtained at a sustain voltage of 170 V in a 7-inch test panel with a long gap (400 µm) structure.

References

[1] Kyung Cheol Choi, Byung-Jong Baek, Heung-Sik Tae, and Hee Dong Park, "Plasma display panel with Ne+N_2 gas-mixture discharges," *IEEE Trans. on Electron Devices*, vol. 50 no. 6, pp. 1440-1444, 2003.

[2] J. Kang, W. G.. Jeon, O. D. Kim, J. W. Song, J. P. Boeuf, and M. H. Park, "Improvement of Luminance and Luminance Efficiency in PDPs Driven by Radio Frequency Pulses," in *Proc. 6th Int. Display Workshop*, pp. 691-694, 1999.

[3] J. Ouyang, Th. Callegari, B. Caillier, and J. P. Boeuf, "Large-gap AC coplanar plasma display cells: macro-cell experiments and 3-D simulations," *IEEE Trans. on PlasmaSscience*, vol. 31, no. 3, pp. 422-428, 2003.

[4] Jae Hyun Lee, Sang Dae Park, Bhum Jae Shin, and Kyung Cheol Choi, "Discharge Characteristics of Coplanar Long-Gap Electrodes in AC PDP with High Xe content," in *Proc. 10th Int. Display Workshop*, pp. 1025-1028, 2003.

[5] Larry F. Weber, United States Patent 6184848B1, 2001.