Characteristics of microplasma modes in a plasma display with an auxiliary electrode

Seung Hun Kim, Jeong Hun Mun and Kyung Cheol Choi
School of Electrical Engineering and Computer Science, KAIST, Daejeon, Korea
TEL:82-42-869-5482, e-mail: shkim77@eeinfo.kaist.ac.kr.

Keywords : Auxiliary electrode, Microplasma mode, Luminous efficacy

Abstract

Microplasma modes generated in a display cell with an auxiliary electrode were investigated in accordance with various coplanar-gaps and plate-gaps. At plate-gaps shorter than the coplanar-gap, the mode transition voltage of the auxiliary pulse increased with an increase in the coplanar-gap. At longer plate-gaps, the mode transition voltage of the auxiliary pulse decreased with an increase in the coplanar-gap.

1. Introduction

Microplasma has been the focus of attention with respect to various applications, particularly plasma display panels (PDPs) and thin film transistor-liquid crystal display (TFT-LCD) back light units (BLUs) [1]. However, the lower efficacy of microplasma is a critical problem and must be solved in order to make it competitive with other technologies. In this regard, understanding the characteristics of microplasma is important to achieve high efficacy [2]. In our previous report, a new structure with an auxiliary electrode was adopted in a plasma display and various microplasma modes generated in the display cell were studied in order to understand the highly efficient microplasma discharge mechanism [3,4]. The proposed structure showed high luminous efficacy for an ac PDP[3]. Furthermore, the microplasma modes were analyzed to explain the behaviors of wall charges[4]. It was speculated that the microplasma modes are strongly dependent on the display structures, such as the coplanar-gap and height of the barrier-rib (plate-gap). The present work investigates the dependency of microplasma modes generated in a display cell with an auxiliary electrode on the coplanar-gap and plate-gap. In particular, the luminous efficacy of microplasma was investigated in accordance with the coplanar-gap and plate-gap in order to determine the optimal conditions for obtaining maximum efficacy in a plasma display device with an auxiliary electrode.

2. Preparation of test panel

Fig.1 shows a schematic diagram of the test plasma devices with an auxiliary electrode. On the front plate, the sustain electrodes and an auxiliary electrode were patterned and coated with a transparent dielectric layer and a MgO layer. The auxiliary electrode was formed at the center of the sustain electrodes.

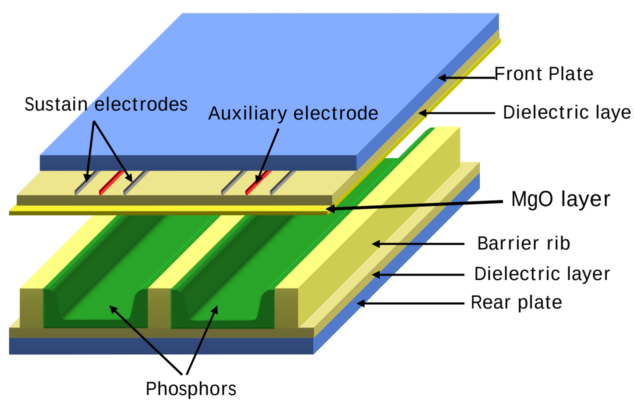


Fig. 1. Schematic diagram of the test panel

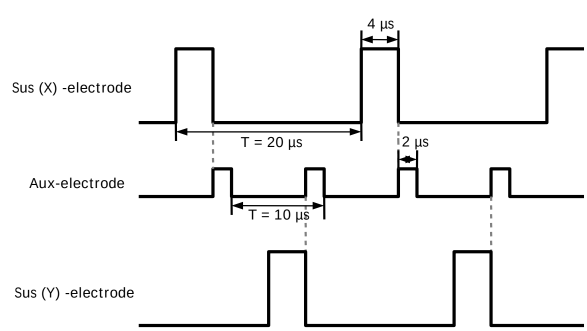


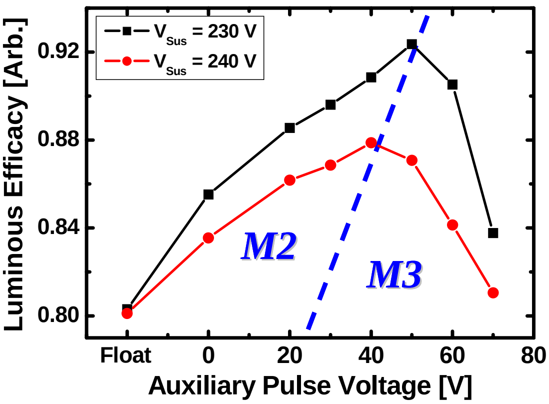
Fig. 2 Pulse waveforms applied to the test panel

On the rear plate, a dielectric layer, barrier ribs, and a green phosphor layer were formed. In contrast with the configuration of a plasma display panel, an address electrode was not formed on the rear plate and the direction of the barrier ribs runs parallel to the sustain electrode so that the effect of the coplanar-gap and plate-gap can be assessed in isolation. Here, the plate-gap was determined by the height of the barrier-rib. The coplanar-gap between the sustain electrodes was varied from 200 to 1,000 μm and the plate-gap was varied from 220 to 2,000 μm. A Ne + 4%Xe gas mixture was used as a discharge gas and the total gas pressure was 500 Torr. Fig.2 shows the pulse waveforms applied to the sustain electrodes and auxiliary electrode. The period of the sustain pulse was 20 μs and its width was 4 μs. The period of the auxiliary pulse, which was applied immediately after the sustain pulse, was 10 μs and its width was 2 μs.

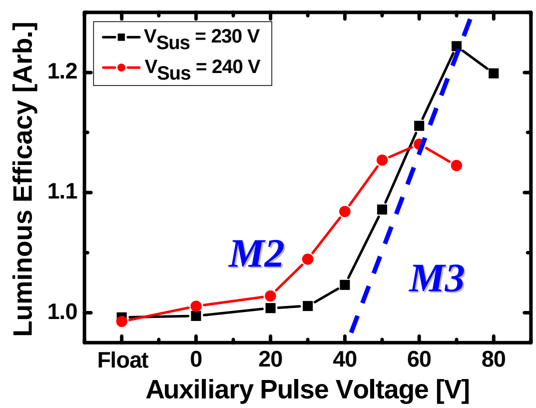
3. Results and discussion

In a previous report, three types of microplasma modes were proposed [4]. Mode 1 showed a decrease in both the discharge current and the discharge delay. Mode 2 showed a decrease in the discharge current and an increase in the discharge delay. Mode 3 showed an increase in the discharge current and a decrease in the discharge delay. From the previous results, it was found that as the voltage of the auxiliary pulse was increased, the efficiency of the microplasma generated in the display cell with an auxiliary electrode increased in modes 1 and 2, but not in mode 3. The effect of variation of the coplanar-gap and plate-gap size on the microplasma modes was investigated in the present work.

Fig. 3 shows the luminous efficacy and microplasma modes for a coplanar-gap of 200 and 300 μm as a function of the auxiliary pulse voltage when the plate-gap was 220 μm. Mode 2 and 3 appeared in the microplasma generated at a plate-gap of 220 μm. In mode 2, the luminous efficacy of 200 and 300 μm coplanar-gap increased as the auxiliary pulse voltage was increased up to 50 and 70 V, respectively because of a reduction in the discharge current. Meanwhile, in mode 3, the luminous efficacy of 200 and 300 μm coplanar-gap decreased when the auxiliary pulse voltage exceeded 50 and 70 V. The decrease in the efficacy is attributed to an increase in the discharge current flowing into the display cell. Additionally, for a plate-gap of 220 μm, the mode transition voltage of the auxiliary pulse was in a range of 40 to 50 V for the coplanar-gap of 200 μm and 60 to 70 V for the 300 μm gap. This mode transition voltage has been shifted to higher auxiliary pulse voltage.



(a)



(b)

Fig.3 Luminous efficacy in accordance with the auxiliary pulse voltage and microplasma modes generated at a plate-gap of 220 μm when (a) the coplanar-gap was 200 μm, and (b) the coplanar-gap was 300 μm

Fig. 4 shows the luminous efficacy in accordance with the microplasma modes and auxiliary pulse voltage for a coplanar-gap of 200 and 300 μm when the plate-gap was 500 μm. Similar to the case of the plate-gap of 220 μm, modes 2 and 3 appeared in microplasma generated at a plate-gap of 500 μm. The behavior of luminous efficacy of the microplasma generated at a plate-gap of 500 μm as a function of the auxiliary pulse voltage corresponded with that observed at a plate-gap of 220 μm. For the plate-gap of 500 μm, the mode transition voltage of the auxiliary pulse was in a range of 30 to 40 V for both the coplanar-gap of 200 μm and 300 μm, which was slightly lower than that a plate-gap of 220 μm.

Stabilized microplasma in the plasma display cell with an auxiliary electrode could not be obtained from a coplanar-gap of 500 ~ 2000 μm at a plate-gap of 220 and 500 μm. From the experiments, it was found that the plate-gap should be extended if the coplanar-gap is greater than the plate-gap.

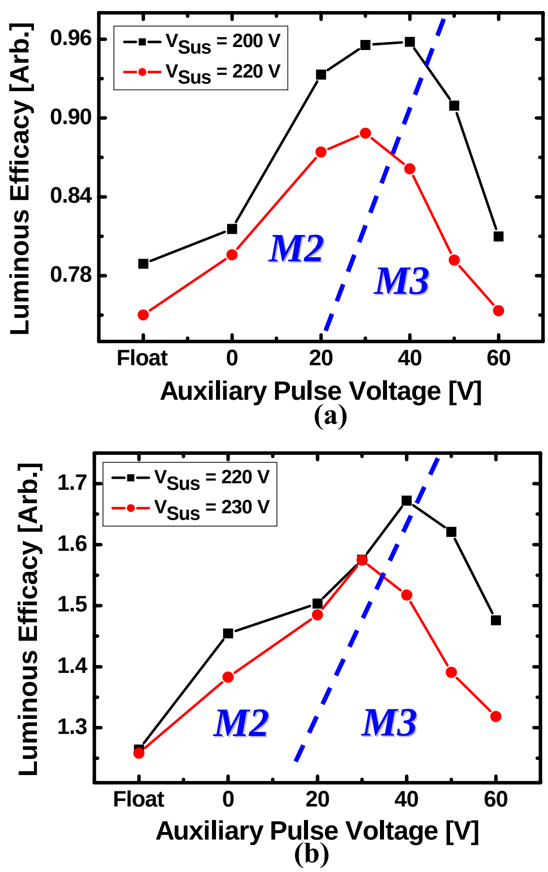


Fig.4 Luminous efficacy in accordance with the auxiliary pulse voltage and microplasma modes generated at a plate-gap of 500 μm when (a) the coplanar-gap was 200 μm, and (b) the coplanar-gap was 300 μm

In order to obtain stable microplasma from a coplanar-gap greater than 500 μm in a display cell with an auxiliary electrode, the plate-gap was extended to 1,100 μm and 2000 μm. Figs. 5 and 6 shows the luminous efficacy in accordance with the auxiliary pulse voltage, the coplanar-gap, and the microplasma modes when the plate-gap is 1,100 μm and 2000 μm, respectively. For the plate-gap of 1,100 μm, coplanar-gaps were 200, 300, and 500 μm. For the plate-gap of 2,000 μm, coplanar-gaps were 200, 300, 500, and 1000 μm. For all cases of coplanar-gaps, modes 2 and 3 appeared and the luminous efficacy corresponded with that of previous cases shown in Figs.3 and 4. For the plate having a 1,100 and 2000 μm gap, respectively, the mode transition voltage of the auxiliary pulse decreased as the coplanar-gap was increased.

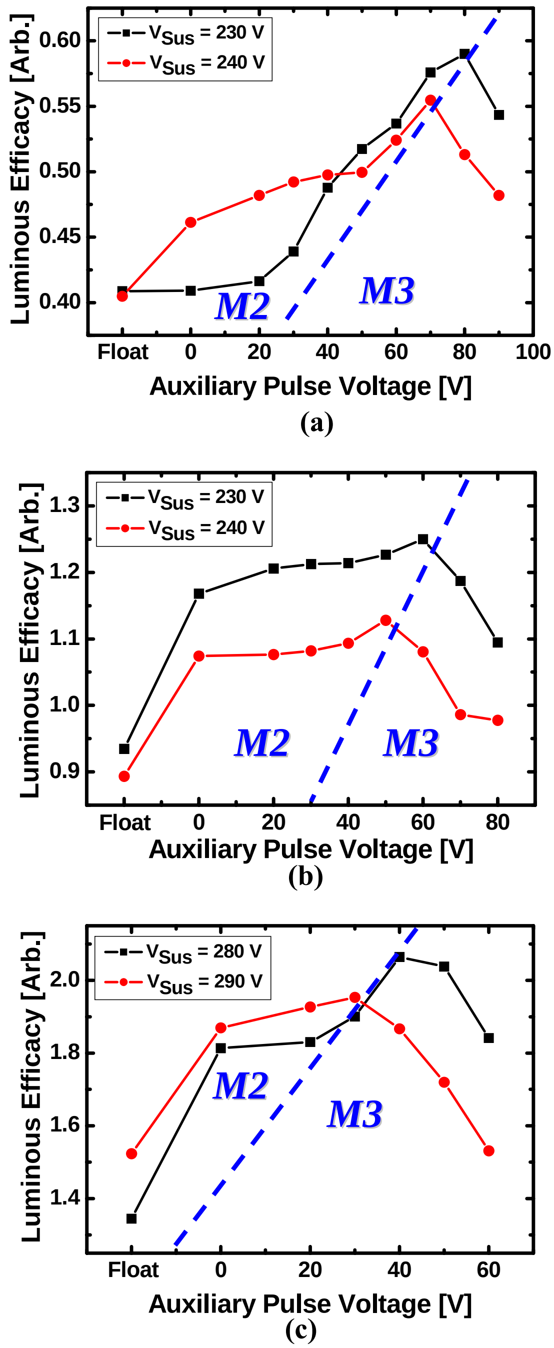


Fig.5 Luminous efficacy in accordance with auxiliary pulse voltage and microplasma modes generated in plate-gap of 1,100 μm when (a) the coplanar-gap was 200 μm, (b) the coplanar-gap was 300 μm, and (c) the coplanar-gap was 500 μm

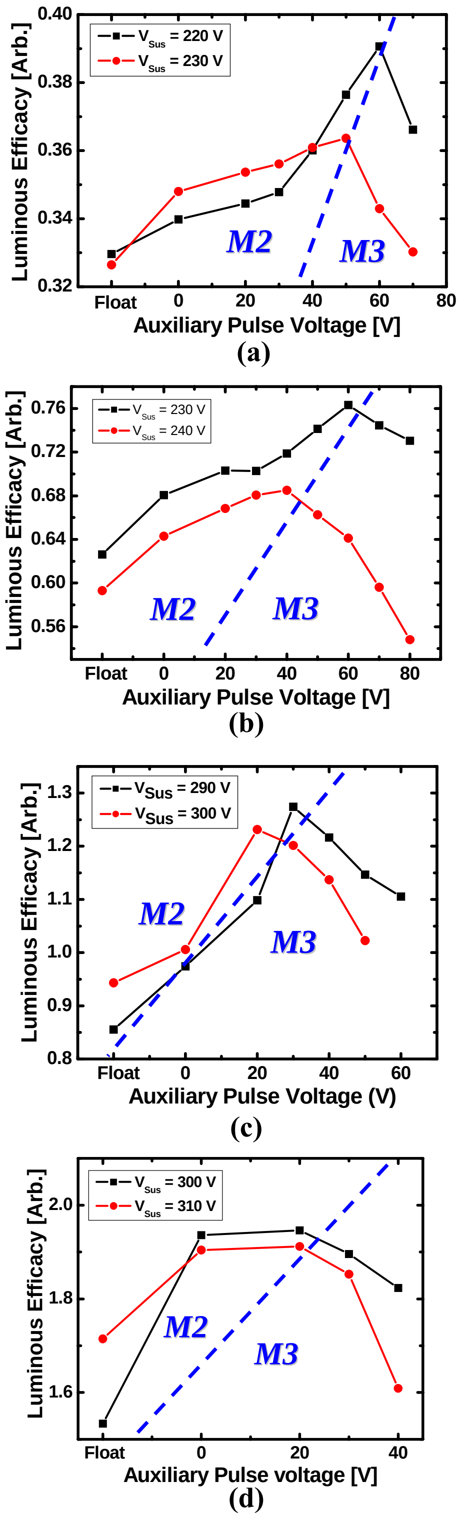


Fig.6 Luminous efficacy in accordance with auxiliary pulse voltage and microplasma modes generated in plate-gap of 2,000 μm when (a) the coplanar-gap was 200 μm, (b) the coplanar-gap was 300 μm, (c) the coplanar-gap was 500 μm, and (d) the coplanar-gap was 1,000 μm

4. Conclusion

The characteristics of microplasma modes in a display cell with an auxiliary electrode were investigated in accordance with various coplanar-gaps and plate-gaps. From the measurement results, it was found that modes 2 and 3 appeared when the coplanar-gap was in a range of 200 to 1000 μm and the plate-gap was in a range of 220 to 2000 μm. The luminous efficacy increased at mode 2 and decreased at mode 3 as the auxiliary pulse voltage was increased. There was a transition voltage of the auxiliary pulse from mode 2 to mode 3. When the plate-gap was shorter than or equals to the coplanar-gap, the mode transition voltage of the auxiliary pulse increased with an increase in the coplanar-gap. However, stable microplasma could not be obtained at a short plate-gap if the coplanar-gap exceeded 500 μm. When the plate-gap was sufficiently longer than the coplanar-gap, the mode transition voltage of the auxiliary pulse decreased with an increase in the coplanar-gap. The results of these parameter studies regarding coplanar-gap and plate-gap can be used to design high luminous efficacy plasma devices with an auxiliary electrode.

5. Acknowledgement

This work was supported by grant No.R01-2006-000-10075-0 from the Basic Research Program of the Korea Science & Engineering Foundation.

6. References

[1] K. H. Becker, K. H. Schoenbach and J. Eden, "Microplasmas and applications," *J. Phys. D: Appl. Phys.*, vol.39, no.3, pp. R55-R70, 2006.

[2] K. C. Choi, N. H. Shin, K. S. Lee, B. J. Shin and S. E. Lee, "Study of various coplanar gaps discharges in ac plasma display panel," *IEEE Trans. Plasma Science*, vol. 34, no. 2, pp. 385-389, 2006.

[3] K. C. Choi, N. H. Shin, S. C. Song, J. H. Lee, and S. D. Park, "A new ac plasma display panel with auxiliary electrode for high luminous efficacy," *IEEE Trans. Electron Devices*, vol. 54, no. 2, pp. 210-218, 2007.

[4] S. H. Kim, J. H. Mun and K. C. Choi, "The effect of the auxiliary electrode on the microplasma generated in a plasma display with a coplanar gap," *IEEE Trans. Plasma Science*, vol. 35, no.3, pp. 650-655, 2007.