Self-Erasing Discharge Mode for Improvement of Luminous Efficiency in AC Plasma Display Panel

Heung-Sik Tae, Byung-Gwon Cho, and Sung-Il Chien

***Abstract*—The current paper proposes a new self-erasing discharge mode to improve the luminous efficiency in an ac plasma display panel (ac-PDP). The self-erasing discharge mode is produced by simultaneous application of auxiliary short pulses to the address electrodes at the falling edges of the sustain pulses. By proper adjusting of the amplitude and width of the auxiliary short pulses, an improved luminous efficiency of 26% and luminance of 9% were simultaneously obtained under the stable driving voltage margin condition (>60 V).**

***Index Terms*—Auxiliary address short pulse, luminance, luminous efficiency, self-erasing discharge, voltage margin.**

I. Introduction

Various driving techniques, such as ramped-square sustain waveform [1], auxiliary address pulse technique [2], and asymmetric pulse driving technique [3], have been suggested to improve the luminous efficiency of an ac plasma display panel (ac-PDP) for the successful realization of large-area (>40 in) digital high-definition televisions (HDTVs). In a sustain period, once the plasma discharge is produced in the cell, the corresponding wall charges are formed abruptly from the space charges such as electrons and ions. These wall charges play an essential role in the next sustain discharge for a stable discharge. However, if the part of wall charges is utilized to produce the priming particles such as space charges under the stable driving voltage margin condition, it is expected that the luminance efficiency will be improved. In this sense, a new sustain discharge mode using a self-erasing discharge has been suggested to improve the luminous efficiency [1], [4]. The physical meaning of the self-erasing discharge is to separate one main discharge into two weaker discharges, i.e., one main discharge and one self-erasing discharge. When the self-erasing discharge is produced, the main discharge and self-erasing discharge currents are decreased but the corresponding infrared (IR) emissions are promoted, due to the presence of the priming particles such as the space charges converted from the part of wall charges. Thus, the luminous efficiency of both the main discharge and the self-erasing discharges is expected to be improved.

The current paper proposes a new self-erasing discharge mode produced by applying an auxiliary short pulse to the address electrode during the application of a sustain pulse. The physical mechanism for triggering the self-erasing discharge of the proposed driving scheme is examined based on the variations in the amplitudes and pulse widths of the auxiliary short pulses. Finally, the effects of the amplitude and width of the auxiliary short pulse on the luminous efficiency, luminance, and voltage margin of a 4-in test panel are discussed.

II. Experiment

A 4-in ac-PDP filled with a He–Ne (7 : 3)–Xe (4%) gas mixture at 400 torr was used as the test panel. The test panel had a conventional ac-PDP structure with stripe barrier ribs and three electrodes such as two sustain electrodes and one address electrode. The red, green, and blue phosphors utilized under the current study were (Y, Gd) BO_3 : Eu, (Zn, Mn)$_2$ SiO_4, and (Ba, Eu) $MgAl_{10}$ O_{17}, respectively. The detailed specifications of the test panel are described in Table I. The driving conditions were a sustain voltage of 180 V, sustain frequency of 50 kHz, and sustain pulse width of 8 μs. No address pulse was applied in the conventional driving scheme, however, the proposed driving scheme applied an auxiliary short pulse to the address electrode simultaneously at the falling edge of a sustain pulse so as to produce a self-erasing discharge. In addition, the amplitude and width of the auxiliary short pulse were varied to investigate their influence on the self-erasing discharge. The currents flowing through the three electrodes were measured in front of the test panel using current meters to calculate the power consumption. The luminance of the visible lights emitted from the test panel was measured using a PR-704 spectrometer. The corresponding IR (823 nm) signals were also detected through an optical fiber and displayed on the digital oscilloscope after being converted to electrical signals by a photomultiplier tube (PMT).

TABLE I
SPECIFICATIONS OF 4-in TEST PANEL EMPLOYING IN CURRENT WORK

Front panel		Rear panel	
ITO width	310 µm	Address electrode width	100 µm
ITO gap	60 µm	Barrier rib height	130 µm
Bus width	100 µm	Barrier rib pitch	420 µm
Dielectric thickness	30 µm	Barrier rib width	80 µm

III. New Self-Erasing Discharge Mode Triggered by Auxiliary Short Pulse

Fig. 1(a) illustrates the schematic waveforms of the sustain pulse V_s and auxiliary short address pulse V_a applied to the three electrodes along with the corresponding sustain current and IR (823 nm) based on the actual waveforms measured from the 4-in test panel during a sustain period in the case of adopting the new driving scheme for a self-erasing discharge. The corresponding temporal behavior model of the wall and space charges within the PDP cell relative to the variations in V_s and V_a is also shown in Fig. 1(b). When the sustain voltage is applied to the sustain electrode, this produces the plasma, as shown in Fig. 1(b)–(i), due to the accumulated wall charges. This is the main discharge that emits the IR shown in Fig. 1(a)–(i). As soon as the plasma is produced, the electrons and ions accumulate on the sustain electrodes X and Y with the opposite polarity, respectively, and a small amount of ions also accumulate on the address electrode with 0 V [Fig. 1(b)–(ii)]. After about 7.4 μs, the auxiliary short pulse V_a with an amplitude of 90 V and a width of 600 ns is applied to the address electrode A. The electric field caused by this abrupt short positive pulse removes a small amount of the positive wall charges accumulated on the address electrode. In addition, as shown in Fig. 1(b)–(iii), the residual negative space charges are accumulated on the address electrode due to the positive auxiliary short pulse because considerable numbers of charged particles remain in a discharge cell for several microseconds after the main discharge [5], as shown in Fig. 1(b)–(ii). The wall charges accumulated on the address electrode from the residual charged particles play a significant role in triggering the self-erasing discharge at the falling edge of the sustain pulse. Consequently, the promotion for the self-erasing discharge is determined by an amount of these wall charges accumulated on the address electrode, which strongly depend not only on the amplitude [Fig. 1(b)–(iii)] but also on the duration time, i.e., width [Fig. 1(b)–(iv)] of the auxiliary short pulse because the wider the width of the auxiliary short pulse is, the larger the amplitude of the auxiliary short pulse is, the more charges are accumulated. In other words, the main role of the

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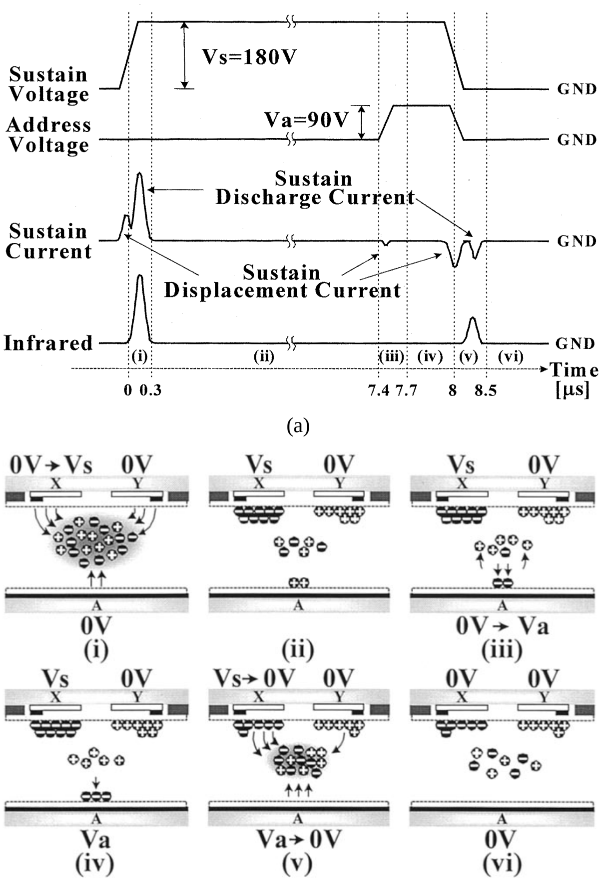

Fig. 1. (a) Voltage, current, and IR (823 nm) waveforms and (b) temporal behavior model of wall and space charges in a 4-in test panel in case of adopting a new driving scheme for self-erasing discharge.

auxiliary short pulse is to trigger the self-erasing discharge by accumulating the wall charges on the address electrode from the residual space charges and providing them at the falling edge of the sustain pulse. As shown in Fig. 1(b)–(v), when both the sustain voltage and the auxiliary voltage abruptly fall to a zero simultaneously, another small discharge, i.e., a self-erasing discharge is induced. In this case, the abrupt falling of both sustain and address voltages causes the conversion of the wall charges accumulated on both the sustain and address electrodes into the space charges, thereby resulting in producing a self-erasing discharge, as shown in Fig. 1(v). Accordingly, this self-erasing discharge can be produced even under a weak electric field condition due to the presence of space charges, implying that the discharge current is decreased due to the reduction of the ionization, but the corresponding IR emission is increased by means of the efficient excitation. That is why the self-erasing discharge contributes to improving the luminous efficiency. The space charges produced during the self-erasing discharge also participates in the next main sustain discharge as the priming particles. The presence of the space charges at the initiation of the ensuing main discharge can also reduce the sustain discharge voltage, thus resulting in lowering the electron temperature [6], [7]. Consequently, the space charges produced during the previous self-erasing discharge contributes to improving the luminous efficiency of the main discharge because the weak electric field condition can promote efficiently the excitation instead of the ionization due to the low electron temperature [7], [8]. By the way, the loss of the wall charges due to the self-erasing discharge would increase the next sustain voltage, whereas the generation of the priming particles such as space charges through the self-erasing discharge would reduce the next sustain voltage. Consequently, the conversion rate of the wall charges into the space charges

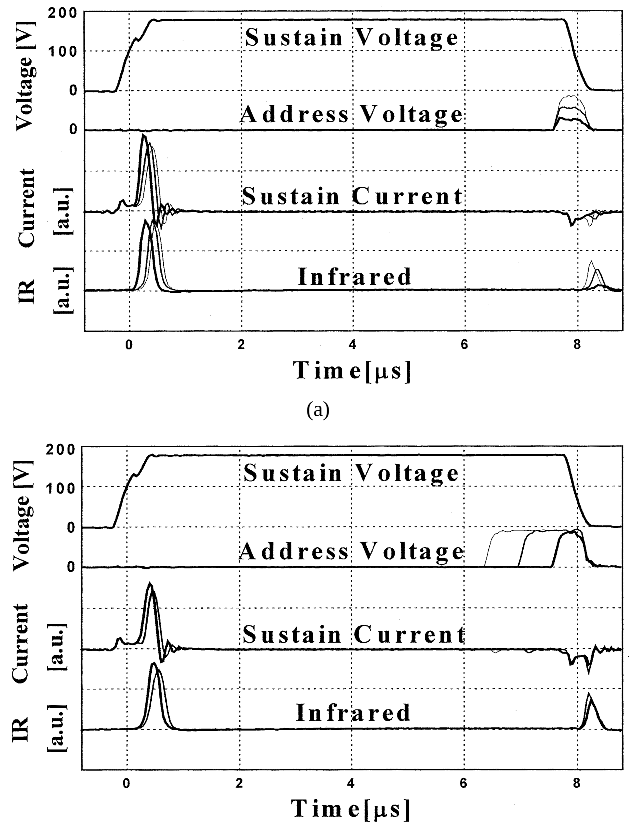

Fig. 2. Current and IR (823 nm) waveforms measured from 4-in test panel in cases of applying auxiliary short pulse with variations of (a) amplitudes and (b) widths.

after the self-erasing discharge determines the driving voltage margin which is a key parameter for the stable driving condition of an ac-PDP. In the case of triggering the self-erasing discharge by the auxiliary short address pulse, the conversion rate between the wall charges and the space charges can be controlled by proper adjusting of the amplitude and duration time of the auxiliary short pulse.

IV. Effects of Amplitude and Width of Auxiliary Pulse on Luminance, Luminous Efficiency, and Voltage Margin

Fig. 2 illustrates the sustain current and IR (823 nm) waveforms measured from the 4-in test panel in the case of adjusting the (a) amplitudes and (b) widths of the auxiliary short pulses. In Fig. 2(a), the widths of the auxiliary short pulses were fixed at 600 ns, whereas the amplitudes ranged at intervals of 30 V from 30 to 90 V. When the amplitude of the auxiliary short pulse was 30 V, there was no self-erasing discharge, indicating that this amplitude was too low to produce the space charges for a self-erasing discharge. When the amplitude was increased from 60 to 90 V, the self-erasing discharge intensity was increased and the main discharge current was decreased. However, the main IR intensity remained almost constant, as shown in Fig. 2(a). This result shows that the higher the amplitude of the auxiliary pulse, the stronger the self-erasing discharge intensity, implying that the high amplitude of the auxiliary pulse can contribute to producing more space charges necessary for the strong self-erasing discharge at the falling edge of the sustain pulse. In Fig. 2(b), the widths of the auxiliary short pulses were increased at intervals of 600 ns from 600 ns to 1800 ns at a constant address voltage of 90 V. As the pulse widths were increased to the direction shown in Fig. 2(b), the IR intensity emitted during the self-erasing discharge was increased, while the IR intensity emitted during the main

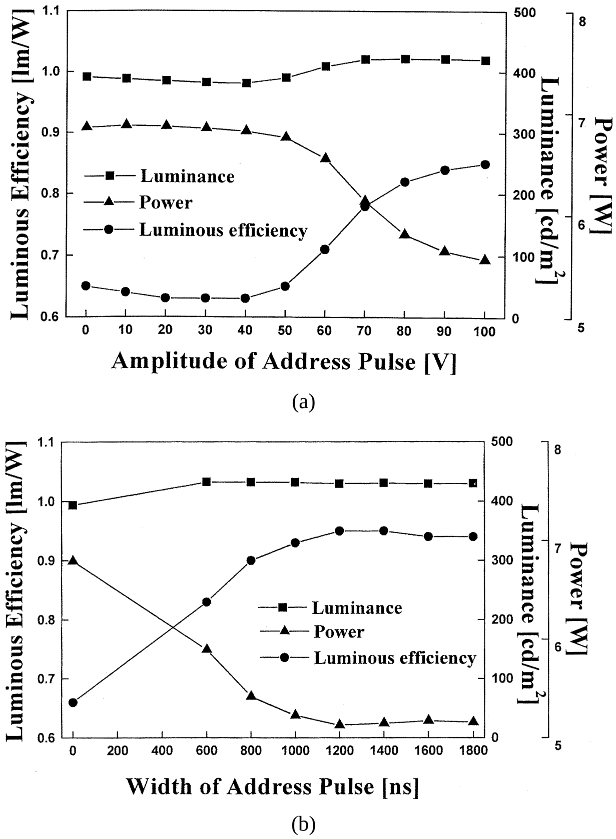

Fig. 3. Luminous efficiency, luminance, and power consumption with variations in (a) amplitudes and (b) widths of auxiliary short pulses in new driving scheme.

discharge was decreased a little and the main discharge current was decreased. As the width of the auxiliary short pulse is wider at a constant address voltage, the self-erasing discharge intensity becomes strong, thereby resulting in improving the luminous efficiency. Like the case of the variation in the amplitude, the wide width of the auxiliary pulse can contribute to producing more space charges necessary for the strong self-erasing discharge at the falling edge of the sustain pulse. Fig. 3(a) and (b) illustrate the changes in the luminous efficiency, luminance, and power consumption relative to an increase in the amplitude and width of the auxiliary short pulse in the new driving scheme. In addition, the changes in the voltages margin were checked with variations of the amplitudes and widths of the auxiliary pulses. The voltage margin is defined as the voltage difference between the firing and sustain voltages. In general, the wide voltage margin (>60 V) is required for the stable driving of a PDP.

The pulse width in Fig. 3(a) was 600 ns, whereas the pulse amplitude in Fig. 3(b) was 90 V. As shown in Fig. 3(a), at the amplitude greater than 50 V, the self-erasing discharge intensity was increased such that the luminous efficiency increased from 9% at 60 V to 27% at 100 V, meanwhile the corresponding luminance was also increased slightly by about 9%. In Fig. 3(b), at constant amplitude of 90 V, as the pulse widths were increased at intervals of 200 ns from 600 ns to 1800 ns, the corresponding luminous efficiency was increased from 26% at 600 ns to 43% at 1200 ns. The improvement in luminous efficiency was found to be almost saturated for the pulse width wider than 1200 ns, as shown in Fig. 3(b).

As the pulse widths were increased at the amplitudes greater than 70 V, the voltage margin was reduced, as shown in Fig. 4. In particular, at the amplitudes greater than 70 V and pulse widths wider than 1000 ns, the voltage margins were found to be reduced to about below 55 V. If the self-erasing discharge is produced, the resultant loss of the wall charges appears to be unavoidable. However, the reduction of the

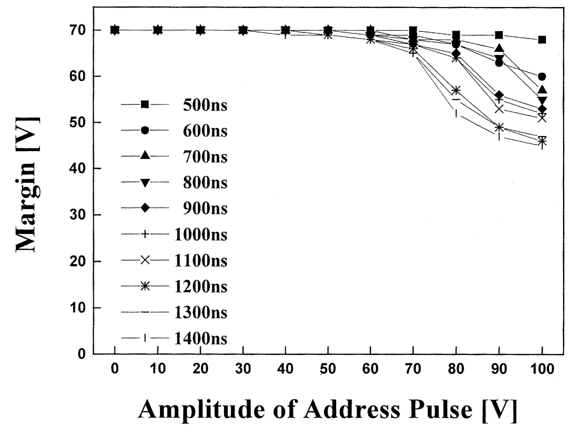

Fig. 4. Voltage margins with variations in amplitudes and widths of auxiliary short pulses in new driving scheme.

break down voltage itself due to the priming effect would compensate the decrease in the voltage margin caused by the loss of wall charges. Nonetheless, if the self-erasing discharge intensity is too strong, the voltage margin is reduced to a great extent due to the excessive loss of the wall charges, even though the high luminous efficiency is obtained. As a result of considering the stable driving voltage margin condition (>60 V), an improved luminous efficiency of 26% and luminance of 8% were simultaneously obtained at the amplitude of 90 V and pulse width of 600 ns.

V. Conclusion

New auxiliary short address pulses for triggering the self-erasing discharge were proposed to improve the luminous efficiency of an ac-PDP. The effects of the amplitude and width in the proposed auxiliary pulse on the luminance efficiency, luminance, and voltage margin of an ac-PDP were investigated. By proper adjusting of the amplitude and width of the auxiliary short pulse, an improved luminous efficiency of 26% and luminance of 8% were simultaneously obtained under the stable driving voltage margin condition (>60 V).

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