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Self-Erasing Discharge Using Ramped-Square Sustain Waveform with Auxiliary Pulse in AC PDP

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In this paper, the effects of an auxiliary pulse on the self-erasing discharge were examined at 100 kHz in the case of adopting the ramped-square sustain pulse in an ac-plasma display panel (ac-PDP). It was found that the auxiliary pulse, which induced no additional discharge current, played a role in strengthening the weak main discharge intensity caused by the previous self-erasing discharge. As a result, the ramped-square sustain waveform with auxiliary pulse improved both the luminance of 20 % and the luminous efficiency of 25 % at 100 kHz, when compared with the conventional square sustain pulse.

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I. INTRODUCTION

In the current PDP technology, the luminance and luminous efficiency need to be further improved for the successful commercialization of full color plasma display panel high definition television (PDP-HDTVs) [1]. Many researches such as reduction of addressing time, new cell structures [2], high frequency driving schemes [3, 4], and so on, has been intensively performed to improve the luminance and luminous efficiency of a PDP. In particular, some research results have been reported for improving the luminous efficiency using the various sustain pulse waveforms that can induce the self-erasing discharge during a sustain-period [5,6]. However, since this self-erasing discharge utilizes the space charges instead of the wall charges for the next sustaining discharge, the luminance tends to be inevitably reduced even though the driving frequency is above 100 kHz. Accordingly, in the case of utilizing the self-erasing discharge, it is necessary to develop the sustain pulse which can control the conversion rate between the space charges and the wall charges for the next sustaining discharge. We have reported the new ramped-square sustain waveform that can induce the self-erasing discharge at low frequency of 62 kHz during a sustain-period [7].

In this work, a new auxiliary pulse is proposed to control the amount of the space or wall charges when the self-erasing discharge is produced by the ramped-square sustain waveform at 100 kHz. The discharge characteristics between the main and self-erasing discharges are examined in the case of adopting the ramped-square sustain waveform with new auxiliary pulse.

II. COMPARISON BETWEEN CONVENTIONAL SQUARE AND RAMPED-SQUARE SUSTAIN PULSE

Figure 1 illustrates the IR (823 nm) waveforms measured from the 4-inch ac-PDP test panel applied with the conventional square and ramped-square sustain pulses, respectively. The conventional sustain voltage of Fig. 1

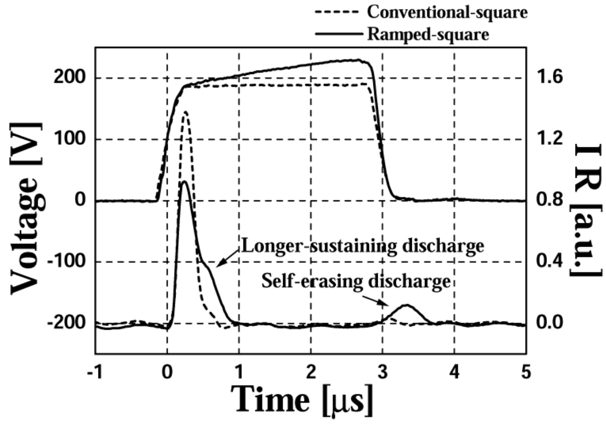

Fig. 1. Voltage and IR waveforms of conventional square and ramped-square sustain pulses.

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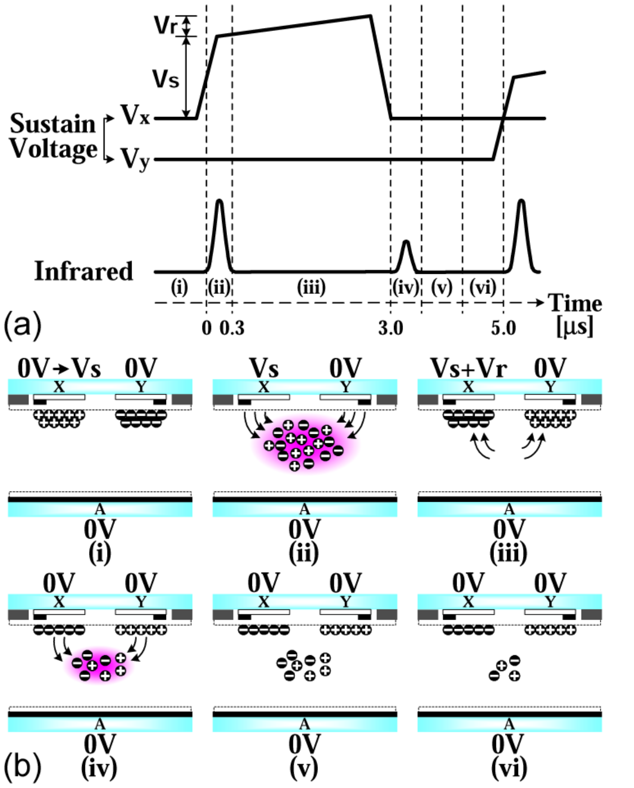

Fig. 2. Ramped-square sustain waveform and its corresponding IR waveform (a), and schematic model for temporal behavior of wall / space charges in 4-inch ac-PDP (b).

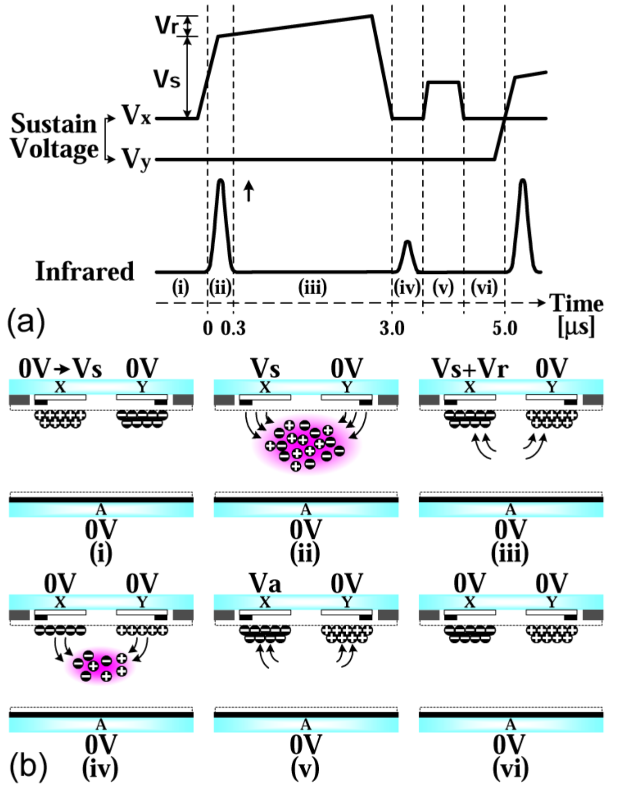

Fig. 3. Ramped-square sustain waveform with auxiliary pulse and its corresponding IR waveform (a), and schematic model for temporal behavior of wall / space charges in 4-inch ac-PDP (b).

is 190 V, whereas, in ramped-square sustain pulse, the amplitudes at the rising and falling edge are 190 V and 230 V (constant slope: 13.3 V/μs). The other driving conditions of Fig. 1 are a frequency of 100 kHz and duty ratio of 30 % (pulse width: 3 μs). The ramped-square sustain waveform is a superimposed waveform, which can add a ramp-waveform to a conventional square sustain waveform with a same pulse width, and has a constantly increasing voltage slope between the rising and falling edges of the sustain pulse, as shown in Fig.1. In the case of a conventional square sustain pulse, the plasma discharge is extinguished immediately because of the accumulation of wall charges with opposite polarity to the applied voltage. Hence, the IR intensity decreases rapidly. The energetic space charges and metastable atoms still remain within the cell after the extinction of the main discharge. In the case of the ramped-square sustain pulse, however, the constantly increasing voltage slope prevents the rapid reduction of an electric field caused by the accumulation of wall charges. Therefore, this sustain waveform can prevent an immediate extinction of plasma discharge, thus resulting in inducing a longer sustaining discharge, as shown in Fig. 1. More energetic space charges and metastable atoms can be utilized in the case of a longer sustaining discharge, thereby contributing to the improvement of a luminous efficiency. After the longer sustaining discharge, the electric field intensity kept constant due to the constantly increasing voltage slope, transforming the space charges into the additional wall charges. This excessively accumulated wall charges can produce a self-erasing discharge at the falling edge of the ramped-square sustain pulse, as shown in Fig. 1. As the self-erasing discharge is produced only by the wall charges, it requires no additional power consumption, thereby improving the luminous efficiency. However, a considerable amount of the wall charges is removed due to the self-erasing discharge, so that the main discharge intensity is more weakened due to the self-erasing discharge in the ramped-square sustain waveform. The detailed physical description of the ramped-square sustain waveform was discussed in our previous work. [4] In this experiment, the luminance and luminous efficiency are improved about 8.8 % and 15 %, respectively, when compared with the conventional square sustain pulse.

III. RAMPED-SQUARE SUSTAIN PULSE WITHOUT / WITH AUXILIARY PULSE

Figure 2 (a) shows the ramped-square sustain waveform without an auxiliary pulse and its corresponding IR (823 nm) waveform [7]. Figure 2 (b) shows the schematic model for temporal behavior of wall / space charges among the three electrodes in the PDP cells in the case of applying the ramped-square sustain pulse without an auxiliary pulse. Figure 3 (a) shows the ramped-square sustain waveform with an auxiliary pulse and its corresponding IR (828 nm) waveform. Figure 3 (b) shows the schematic model for temporal behavior of wall / space charges among the three electrodes in the PDP cells in the case of applying the ramped-square sustain pulse with an auxiliary pulse. The IR emissions in the region of (ii) in Figs. 2 (a) and 3 (a) are produced in the main discharge, whereas the IR emissions in the region of (iv) in Figs. 2 (a) and 3 (a) are produced in the self-erasing discharge. These self-erasing discharges in (iv) of Figs. 2 (b) and 3 (b) are produced by accumulating the excessive wall charges, as shown in (iii) of Figs. 2 (b) and 3 (b), due to the increasing voltage slope in the ramped-square pulse. As shown in (v) of Fig. 2 (b), since the voltages applied to the two sustain electrodes are zero after the self-erasing discharge, lots of space charges are produced and only a few wall charges are remaining on the electrodes, thereby resulting in weakening the main discharge intensity. In general, this weak main discharge due to the self-erasing discharge may cause the reduction of the luminance. However, in the case of (v) of Fig. 3 (b), since the voltage of the auxiliary pulse, Va is applied to the sustain electrode, more wall charges can be accumulated immediately after the self-erasing discharge, thereby resulting in compensating the weak main discharge. This compensation of the weak main discharge can contribute to increasing the luminance.

IV. RESULTS AND DISCUSSION

1. Effects of Starting Points in Auxiliary Pulse on Luminance and Luminous Efficiency

Figure 4 shows the voltage, infrared (IR: 823 nm) waveforms (a) measured from the 4-inch ac-PDP test panel and its corresponding luminance / luminous efficiency / consumption power (b) as a variation of the starting point of auxiliary pulse from the falling edge of the ramped-square sustain pulse. The driving conditions are a frequency of 100 kHz, pulse width of 3 μs, auxiliary pulse width of 0.4 μs, and its amplitude of 40 V. When the auxiliary pulse is applied at 3.5 μs from the falling edge of the ramped-square sustain pulse, indicating that the auxiliary pulse is applied during the self-erasing discharge, the self-erasing discharge is abruptly extinguished, so that the main discharge becomes strong. In this case, the luminance and luminous efficiency are low due to the perturbation of the self-erasing discharge caused by the auxiliary pulse, as shown in Fig. 4 (b). If the auxiliary pulse is applied at 3.9 μs, indicating that the auxiliary pulse is applied immediately after extinction of the self-erasing discharge, the self-erasing discharge has not been affected from the auxiliary pulse. At this time, the auxiliary pulse contributes to compensate the loss of wall charges due to the self-erasing discharge, and the resulting main discharge intensity becomes weak a little, compared with the main discharge intensity without self-erasing discharge. As a result, both the luminance and luminous efficiency are shown to be the maximum values at the starting point of 3.9 μs from the falling edge of the ramped-square sustain pulse.

2. Effects of Pulse Widths in Auxiliary Pulse on Luminance and Luminous Efficiency

Figure 5 illustrates the voltage, infrared (IR: 823 nm) waveforms measured from the 4-inch ac-PDP test panel (a) and its corresponding luminance / luminous efficiency / consumption power (b) as a variation of the width of auxiliary pulse in the ramped-square sustain pulse. The driving conditions are a frequency of 100 kHz, pulse width of 3.0 μs, and the auxiliary pulse has a starting point of 3.9 μs from the falling edge and amplitude of 40 V. The main discharge and the related self-erasing

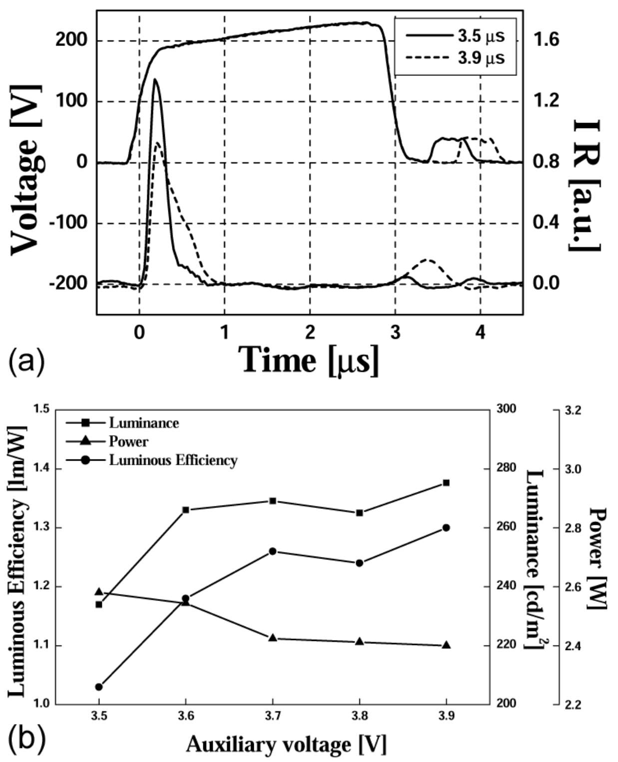

Fig. 4. Voltage, IR waveform (a) and luminance / luminous efficiency / consumption power (b) with variations of starting points of auxiliary pulses in ramped-square sustain pulse.

discharge change a little, as the auxiliary pulse width increases, because the auxiliary pulse is applied after the extinction of the self-erasing discharge, which indicates that the luminance and luminous efficiency change little as shown in the luminance and luminous efficiency data of Fig. 5 (b). This result implies that the pulse width of the auxiliary pulse in the ramped-square sustain waveform does not affect both the main and the self-erasing discharges.

3. Effects of Pulse Amplitudes in Auxiliary Pulse on Luminance and Luminous Efficiency

Figure 6 shows the voltage, infrared (IR: 823 nm) waveforms (a) measured from the 4-inch ac-PDP test panel and its corresponding luminance / luminous efficiency / consumption power (b) as a variation of the amplitude of the auxiliary pulse in the ramped-square sustain pulse. The driving frequency is 100 kHz and its pulse width is 3 μs, and the auxiliary pulse has a starting point of 3.9 μs from the falling edge, and width of 0.4 μs, as shown in Fig. 6 (a). Since the auxiliary pulse is applied immediately after extinction of the self-erasing discharge, it does not affect the next self-erasing discharge. As mentioned in Fig. 3 (b), the main discharge is intensified due to more wall charges accumulated by the auxiliary pulse, implying that this auxiliary pulse plays a significant role in strengthening the next main discharge after the self-erasing discharge. Consequently, the luminance and luminous efficiency are improved simultaneously with an increase in the amplitude of the auxiliary pulse. When compared with the ramped-square sustain pulse without an auxiliary pulse, the luminance of 10 % and luminous efficiency of 8 % are simultaneously improved at a frequency of 100 kHz and a pulse width of 3 μs by applying the auxiliary pulse in the ramped-square sustain waveform during a sustain-period.

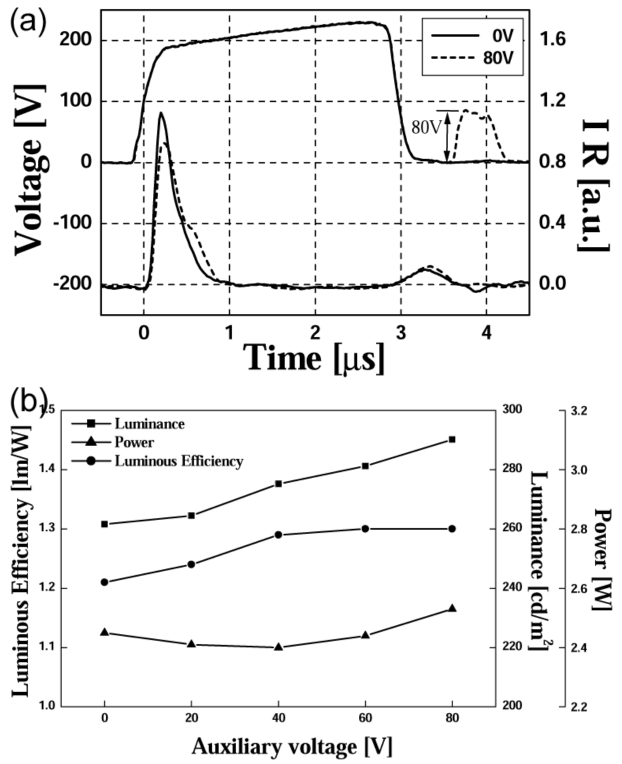

Fig. 6. Voltage, IR waveform (a) and luminance / luminous efficiency / consumption power (b) with variations of pulse amplitudes of auxiliary pulses in ramped-square sustain pulse.

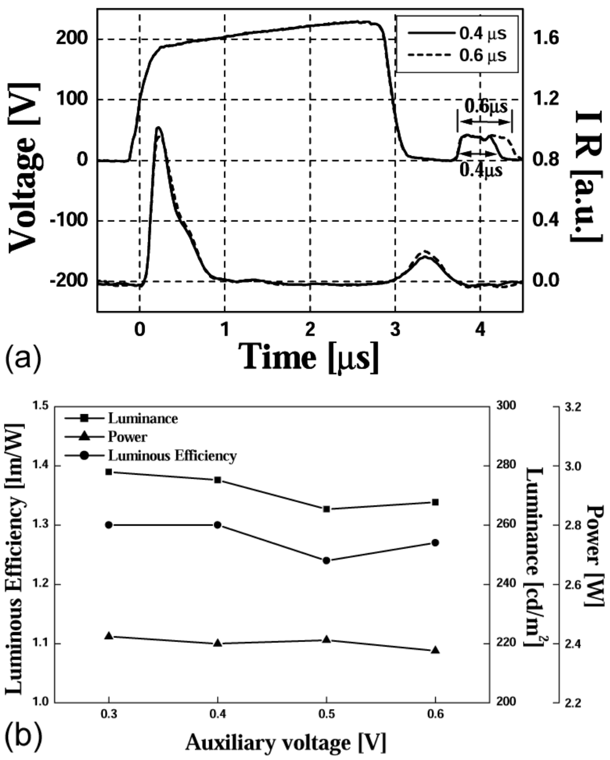

Fig. 5. Voltage, IR waveform (a) and luminance / luminous efficiency / consumption power (b) with variations of pulse widths of auxiliary pulses in ramped-square sustain pulse.

V. CONCLUSION

The ramped-square sustain waveform with an auxiliary pulse is proposed to compensate the weak main discharge caused by the previous self-erasing discharge. When compared with the conventional square sustain waveform, both the luminance of 20 % and luminous efficiency of 25 % are improved at the frequency of 100 kHz and a pulse width of 3 μs in the case of adopting the ramped-square sustain waveform with an auxiliary pulse. It is expected that the luminance and luminous efficiency can be simultaneously much improved if the relation between the auxiliary pulse and the ramped-square pulse is properly controlled.

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