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# Improvement of Plasma Discharge Characteristics in Blue Cells of AC Plasma Display Panel Using Auxiliary Pulse Driving Scheme

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In order to improve the luminance in blue cells, which has been one of serious problems in a conventional plasma display panel, the application of an auxiliary short pulse to the address electrode in blue cell during a sustain-period is suggested. This driving scheme changes the discharge phenomena in a blue cell and affects the operating voltage margin, that is, the difference between firing voltage and sustain voltage, and undesired firing. In this study, an auxiliary short pulse driving scheme for improving the plasma discharge characteristic in blue cells is proposed and its effects on the operating voltage margin and undesired firing are also investigated.

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## I. INTRODUCTION

Plasma Display Panel (PDP) has been highlighted as one of the potential display devices for the large area (>40-inch) full color wall-hanging digital high definition televisions (HDTVs) [1,2]. However, there are still many technical problems to overcome for the successful commercialization. In particular, lower luminance of blue cells than that of red and green cells has been one of serious problems, which causes a poor color image quality due to a low white color temperature. Recently, a variety of methods such as asymmetric cell structure and asymmetric sustain electrodes have been tried to enhance the blue luminance [3,4]. However, these methods may induce unstable operation such as small operating voltage margin and undesired firing by the different conditions between each cell. So far, studies on considering the operating voltage margin and undesired firing have been insufficient. There exist millions of cells in PDP and each of these cells has somewhat different operating voltage. Therefore, the margin of operating voltage should be large enough to operate the panel stably since one fixed operating voltage within the margin controls every different operating voltage between each cell when operated [5,6]. We have previously presented that the proper auxiliary short pulses on the address electrodes during a sustain-period can contribute to improving the luminance [7]. In this study, we focus on the improvement of luminance in blue cells by applying auxiliary short pulses to the address electrodes in only blue cells during a sustain-period and investigate its effect on the operating voltage margin or undesired firing.

## II. EXPERIMENTAL DETAILS

Figure 1 (a) shows the schematic diagram of an optical and electrical measurement system for 7-inch ac-PDP test panel employed in this study and the fundamental structure of a single pixel in AC-PDP. It consists of the front substrate with the sustain electrodes including ITO and bus electrode, a dielectric layer, and MgO layer and the rear substrate with the address electrode, barrier rib, and phosphor. The electric energy caused by the voltage applied to each electrodes, which is high enough to ignite a discharge within a cell, induces the excitation and ionization of the gas and plasma discharge. The VUV(vacuum ultraviolet) from the plasma discharge stimulates the phosphor and the IR(infrared radiation) is emitted as the excited phosphor falls to the ground state. Fig. 1(b) illustrates the voltage waveforms $V_X$ and $V_Y$ applied to the sustain electrodes X and Y, and an auxiliary short pulse $V_A$ applied to the address electrode Z. The pressure of 400 Torr and the gas mixtures of Ne-Xe-He are used in the test panel. The driving conditions are a sustain frequency of 50 kHz with 40 % duty ratio and a sustain voltage of 160 V. Auxiliary pulses are varied from 0 V to 120 V in amplitudes and from 0 $\mu$s to 5 $\mu$s in widths. A new auxiliary short pulse VA and sustain voltage pulses VX and VY are simultaneously applied to the three electrodes during a sustain-period, respectively. The time variations in the intensity of Infrared Radiation (IR) of 823 nm are measured by monochromator and Photo-Multiplier-Tube (PMT). The CIE chromaticity coordinates and light emission spectra in blue cells are observed by PR-704 spectrometer.

## III. RESULTS AND DISCUSSION

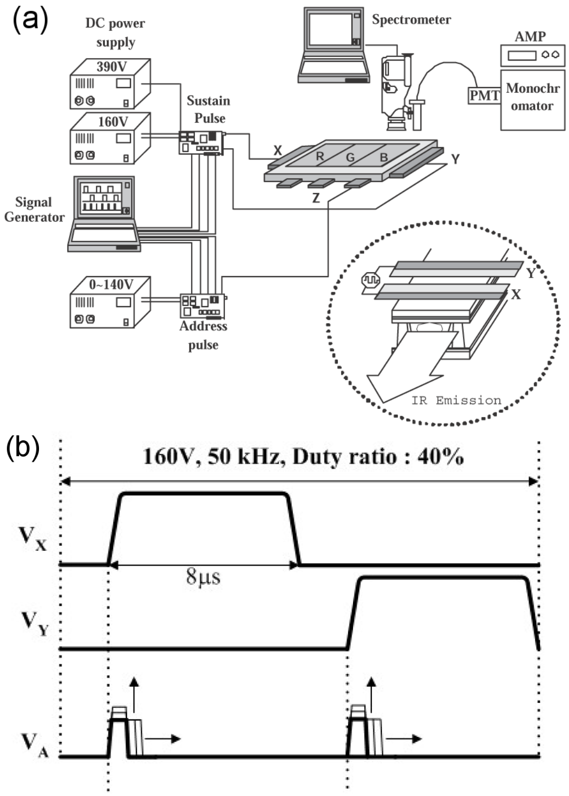


Fig. 1. Measurement system and the structure of a single pixel in AC-PDP(a) and driving voltage waveforms with auxiliary address pulses(b).

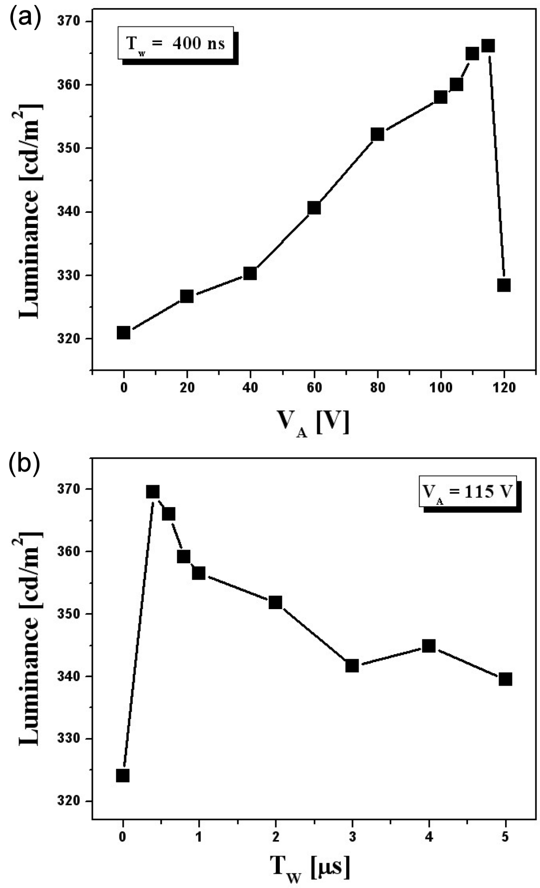


Fig. 2. changes in blue luminance with various amplitudes of auxiliary short pulses(a) and changes in blue luminance with various widths of auxiliary pulses(b).

Figure 2 (a) and (b) show the changes in blue luminance with various amplitudes and widths of auxiliary short pulses applied to the address electrode during a sustain-period, respectively. The luminance is improved until the auxiliary voltage of 115 V and reduced abruptly with the voltages higher than 115 V. In case of pulse widths, the luminance is relatively greatly enhanced within a range of 0.4 $\mu$s $\sim$1 $\mu$s. In particular, the maximum enhancement of luminance in blue cells is obtained with the increase of 14% by the auxiliary short pulse having the amplitude of 115 V and the width of 400 ns.

Figure 3 (a) and (b) illustrate time-resolved emission spectra of IR (823nm) from the blue cells of 7-inch test panel as a function of various amplitudes and widths of auxiliary pulses, respectively. Fig. 3(a) describes that the higher the amplitude of an auxiliary short pulse is, the higher the peak intensity of IR is and more leftward it shifts. Fig. 3(b) shows that the pulses having the widths of 400 ns$\sim$1$\mu$s have the highest peak and most leftward shift. The maximum intensity of IR is obtained with the auxiliary pulse of which amplitude and width are 115 V and 400 ns, respectively. According to the mechanism mentioned in the reference [7], the auxiliary short pulse on the address electrode induces the drift motions of space charged particles toward the address electrode, resulting in the increase of the peak intensity of IR and improvement of luminance. Moreover, it is thought that the electrons drifted toward the address electrode additionally produce the space charged particles, resulting in the leading of discharge compared to the conventional case.

Figure 4 (a) and (b) illustrate the changes in the operating voltage margin with various amplitudes and widths of auxiliary short pulses, where $V_f1$ is the minimum firing voltage at which the subpixel can ignite a discharge without wall charge, $V_fN$ is the maximum one at which discharge ignites in all cells, $V_s1$ is the minimum voltage at which the subpixel can maintain the discharge with previously accumulated wall charges, and $V_sN$ is the voltage at which the discharge turns off in the last cell. As a result, firing voltages, $V_f1$ and $V_fN$ are not much dependent on both amplitudes and widths of auxiliary pulses. On the other hand, the sustain voltages are decreased with the increase in the amplitudes of the auxiliary pulses until 115 V at which the maximum luminance is obtained and increased at 120 V. They are also decreased with the pulses having short width of 400 ns.

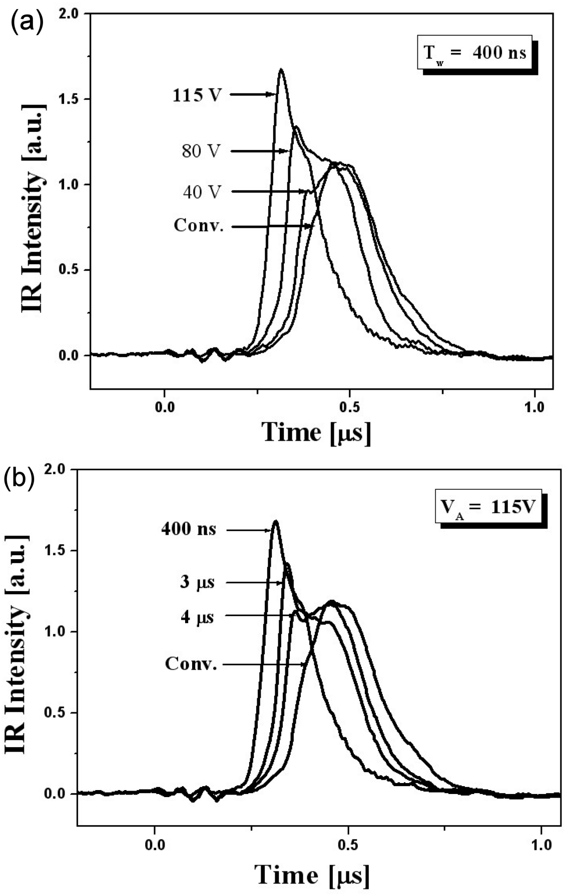


Fig. 3. Changes in IR intensity with various amplitudes of auxiliary short pulses(a) and changes in IR intensity with various widths of auxiliary pulses(b).

Figure 5 (a) and (b) show the wall charge model of discharge in blue cells in the case of conventional driving scheme (a) and suggested driving scheme (b). As shown in (i) of Fig. 5(a) and (b), wall charges, which have been produced by the previous sustain voltage pulses, are accumulated on the dielectric layer below the two sustain electrodes. At this point, if the sustain voltage pulse of 130V is applied to the sustain electrode X, discharge is not produced within the cell since the electric field intensity generated by the sustain voltage of 130V plus the wall voltage due to previously accumulated wall charges is not enough to satisfy the breakdown condition of discharge as shown in (ii) of Fig. 5(a). On the other hand, as the auxiliary pulse of 115V is additionally applied to the address electrode as shown in (ii) of Fig. 5(b), the electric field is also induced between the sustain electrode Y and address electrode Z. Accordingly, unlike (ii) of Fig. 5(a), the plasma is produced between the sustain electrode and the address electrode as well as between two sustain electrodes. This indicates that additional electric field induced by the auxiliary pulse can decrease the sustain voltage, resulting in the increase of voltage margin.

Figure 6 shows the driving waveforms used in this study to investigate the undesired firing problem. Voltage conditions of driving scheme which consists of erasing pulse, ramp type reset pulse, and sustain pulses during reset, address, and sustain periods are shown in Fig. 6 [8]. Undesired firing occurs when the discharge ignites in the cells where no data pulse is applied during an address-period or when no discharge ignites in the cells where data pulse is applied during an address-period. We determined the undesired firing region by measuring the voltages at which discharge ignites with the auxiliary short pulses applied to the address electrode during a sustain-period when no data pulse was applied during an address-period.

Figure 7 shows the regions for the stable operation and the undesired firing with various widths of the auxiliary pulses. As the width of an auxiliary pulse increases, the voltage for the stable operation gets lower. In Fig. 2 and 4, we found optimal condition for luminance and voltage margin at pulse amplitude of 115 V and pulse width of 400 ns. As shown in Fig. 7, this optimal auxiliary pulse is located in the stable operation region, implying that

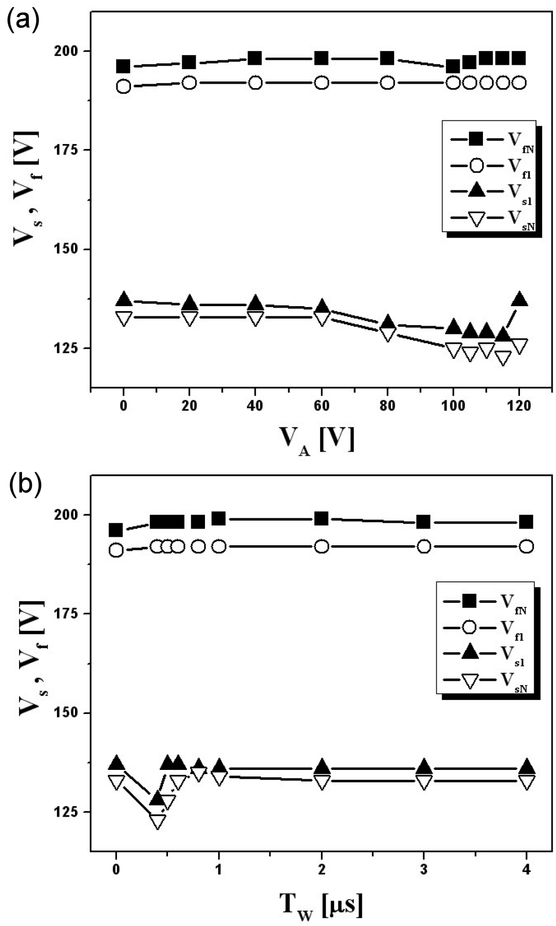


Fig. 4. Operating voltage margin with various amplitudes of auxiliary short pulses(a) and operating voltage margin with various widths of auxiliary pulses(b).

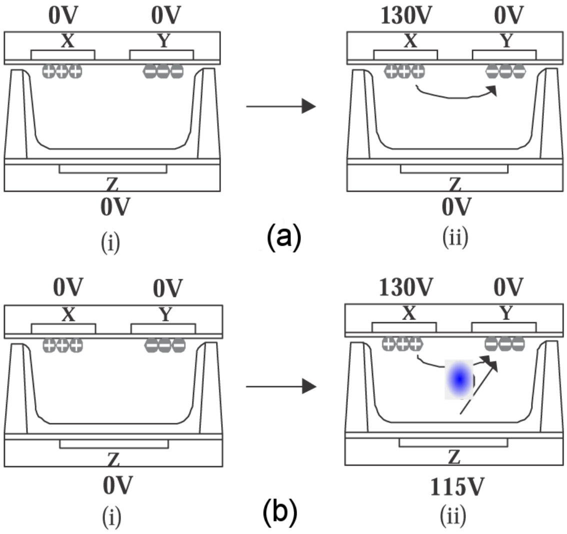


Fig. 5. Wall charge model in the case of (a) conventional driving method, and (b) suggested driving method with auxiliary short pulses.

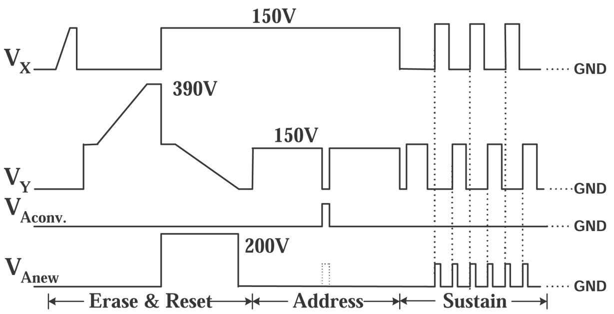


Fig. 6. Driving waveforms to investigate the undesired firing.

this driving method using auxiliary short pulse during a sustain-period can improve the luminance of blue light without affecting driving operations such as voltage margin and undesired firing.

## IV. CONCLUSIONS

The effects of auxiliary voltage pulses, which are applied to the address electrode in blue cells during a sustain-period, on the luminance, voltage margin, and undesired firing were investigated in the surface-discharge of a 7-inch AC-PDP test panel. The maximum enhancement of luminance in blue cells was obtained with the increase of 14 % by optimal condition of the auxiliary short pulse having the amplitude of 115 V and the width of 400 ns. The voltage margin was shown to be enlarged up to 10 V in the case of auxiliary pulse having the width of 400 ns and amplitude of 115V, compared with the conventional driving scheme. Furthermore, these optimal conditions was located in the stable operation region, implying that this driving method using auxiliary short pulse can improve the luminance of blue light without affecting driving operations such as voltage margin and undesired firing.

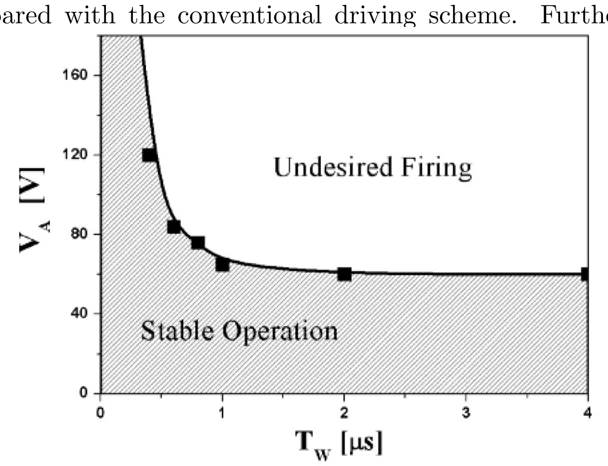


Fig. 7. Regions for stable operation and undesired firing.

## V. FUTURE WORKS

When the proper auxiliary short address pulses are simultaneously applied to the address electrode of blue cells during a sustain-period, the spreading phenomena of the charged particles from the region near the sustain electrodes toward the address electrode region will be observed by the direct measurement method.

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