Reduction of Ne Emission Using New Driving Scheme in AC-PDPs

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Abstract

A new driving scheme is proposed to improve the color purity by reducing the neon (Ne) emission of 585 nm in an ac PDP. Applying the new driving scheme to the address electrodes during a sustain-period induces a new discharge mode that can reduce the Ne emission remarkably. For this new discharge mode, the change in the Ne emission intensity including the discharge characteristics is measured and the corresponding mechanism is also analyzed. As a result, it is found that a color gamut area is expanded by approximately 9.2 % in comparison with a conventional case.

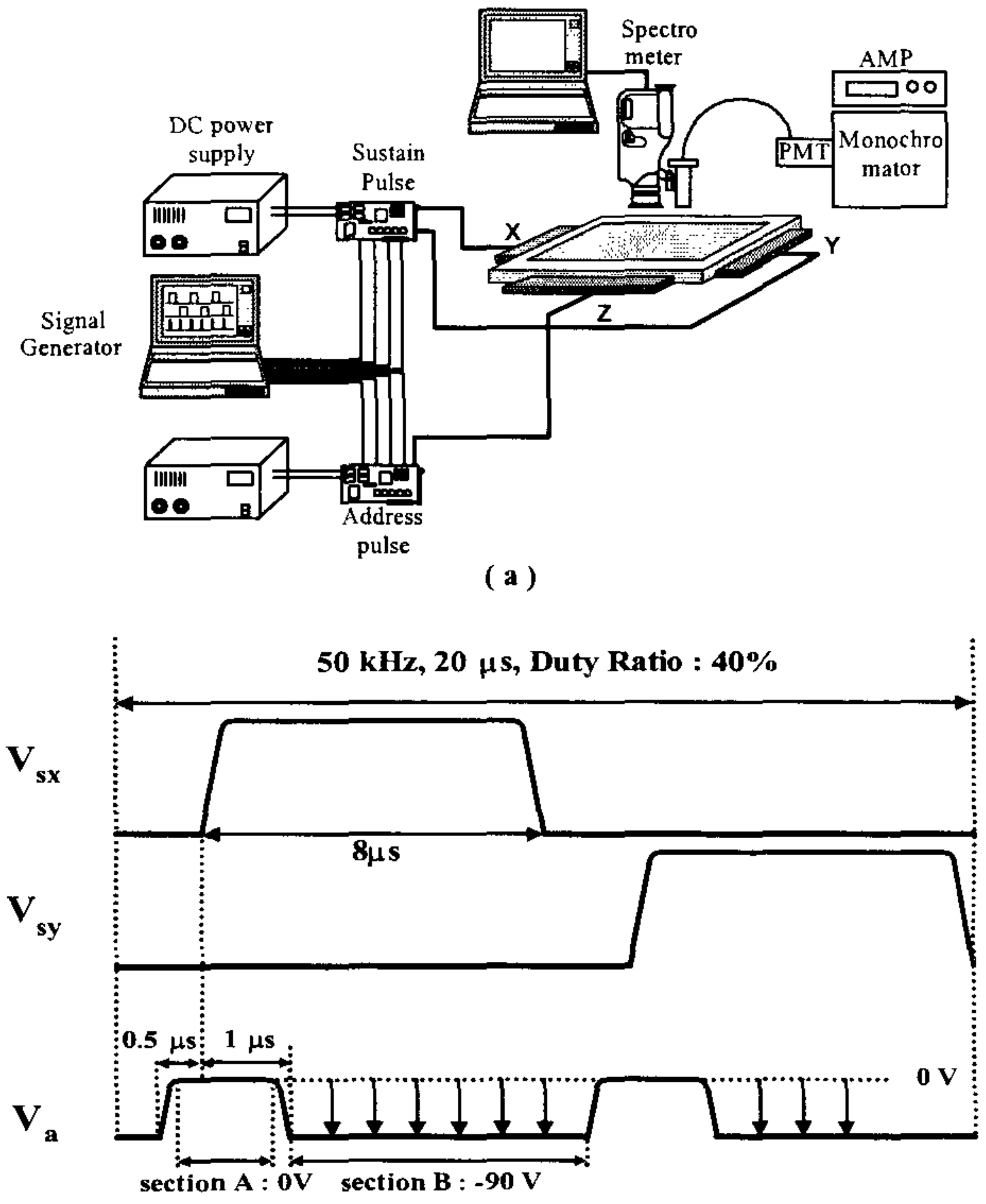
. INTRODUCTION

Up to now, lots of researches related to improving luminance, luminous efficiency and fabrication cost in ac-PDP have been being performed. Then, those characteristics are improving gradually. With those improvements, the importance of display image quality that is one of the most important properties to customers is growing up. Regarding the improvement of the display image quality, it is well known that the color reproducibility of PDP is lower than that of NTSC and it must be improved. Several researches related to improving color reproducibility have been performed to reduce the Ne emission by using various methods, for instance, using the optical filter or using the optimization of the gas chemistry, as well as improving the color purity of red, green, and blue phosphor material itself [1]. Through those researches, the color reproducibility of PDP is slightly improved. However, those improvements are still far away from the level of NTSC.

In this paper, in order to improve the color reproducibility, new auxiliary negative pulse is developed and applied to the address electrodes during a sustain-period. The characteristics on the new discharge mode produced by the auxiliary negative pulse are examined by measuring the Ne emission intensity and the related discharge mechanism is also analyzed. Finally, the improvement of a color gamut is examined based on the reduction of Ne emission using the new auxiliary negative pulse.

. Experimental Setup and New Driving Scheme

Fig. 1 (a) shows the optical measurement system for measuring the electrical and optical characteristics of the 7-inch ac-PDP test panel employed in this research. Fig. 1 (b) shows the voltage waveforms V_{sx} and V_{sy} applied to the sustain electrodes X and Y, and new auxiliary negative pulse V_a applied to the address electrode Z. The pressure of 400 Torr and the gas mixture of Ne-Xe-He are used in this panel. As shown in Fig. 1, the sustain voltage pulses with amplitude of 170 V and duty ratio of 40 % are applied at the frequency of 50 KHz. New auxiliary negative pulse is simultaneously applied to the address electrodes during a sustain-period. New auxiliary negative pulse consists of two sections of pulses with different widths and voltage levels. The auxiliary negative pulse of section A keeps a constant voltage of 0 V, *i.e.* base level, for 0.5 μsec before applying the sustain pulse V_{sX} and for 1 μsec during the appliance of the sustain pulse V_{sX} . On the other and, the auxiliary negative pulse of section B begins at 1 μsec after the sustain pulse V_{sX} is applied and ends at 0.5 μsec before the subsequent sustain pulse V_{sY} is applied. For the new negative pulse, the width of section A (base level) is shorter than that of section B (negative level). These types of sustain pulses and auxiliary negative address pulses are periodically applied to the sustain electrodes X, Y and the address electrode Z during a sustain-period, respectively. In other words, there are two sustain pulses (V_{sX}, V_{sY}) and two auxiliary negative pulses in one sustain period. The test panel is driven by those sustain pulses and new negative pulses suggested in this paper. The time variations in the peak intensities of infrared radiation (IR) of 823 nm and Ne plasma emission of 585 nm are measured by using monochromator and Photo-Multiplier-Tube (PMT). The CIE chromaticity coordinates and emission spectrum of R, G and B lights are also measured by using PR-704 spectrometer.



(a)

(b)

Fig. 1. Optical measurement system (a) and applied sustain pulses with new auxiliary negative pulses (b).

. RESULTS AND DISCUSSION

Fig. 2 illustrates the time-resolved emission spectra of the IR (823 nm) and Ne (585 nm) measured from the blue cells of the 7-inch AC PDP test panel when employing either conventional sustain pulses with no auxiliary pulses or sustain pulses along with the new auxiliary negative pulses during a sustain period. Since IR at 823 nm is a precursor for excited Xe atoms generating a vacuum ultraviolet (VUV) at 173 nm, the discharge characteristics and VUV emission characteristics can be indirectly analyzed from the IR waveforms [2]. In the case of the conventional sustain pulses with no auxiliary pulses, the IR and Ne emission waveforms exhibited a single peak per sustain pulse, as shown by the dotted line in Fig. 2. In contrast, in the case of the sustain pulses with the new auxiliary negative pulses, the IR and Ne emission waveforms were found to have double peaks per sustain pulse. However, the two double peaks of the IR and Ne emission waveforms for the sustain pulses V_{sx} and V_{sy} were asymmetrical in shape, height, and relative position, as shown by the measured waveforms in Fig. 2. For the sustain pulse V_{sx}, the first peaks were lower than the second peaks, plus the second peak of the IR waveform almost had the same intensity as that in the conventional driving case. For the sustain pulse V_{sy}, the first peaks were also lower than the second peaks, yet higher than those for the sustain pulse V_{sx}. For the sustain pulse V_{sy}, the second peak intensity of the IR waveform was slightly lower than that of the conventional driving case, whereas the second peak intensity of the Ne emission was considerably reduced compared with that of the conventional driving case. Furthermore, the second IR and Ne emission double peaks were shifted to the left, thereby implying that the plasma was produced before the sustain voltage V_{sy} applied to the blue cells reached the maximum voltage. Accordingly, this experimental result confirms that the auxiliary negative pulse contributed to the production of priming particles, which play an important role in lowering the Ne emission intensity. To analyze the Ne reduction mechanism, the period during which the sustain pulses V_{sx}, V_{sy} and negative pulse V_a were applied was divided into two modes, and , as illustrated in Fig. 3. For the two modes, and , the corresponding discharge characteristics and Ne reduction mechanism are described in the temporal behavior of the wall charges within the cells in Fig. 4.

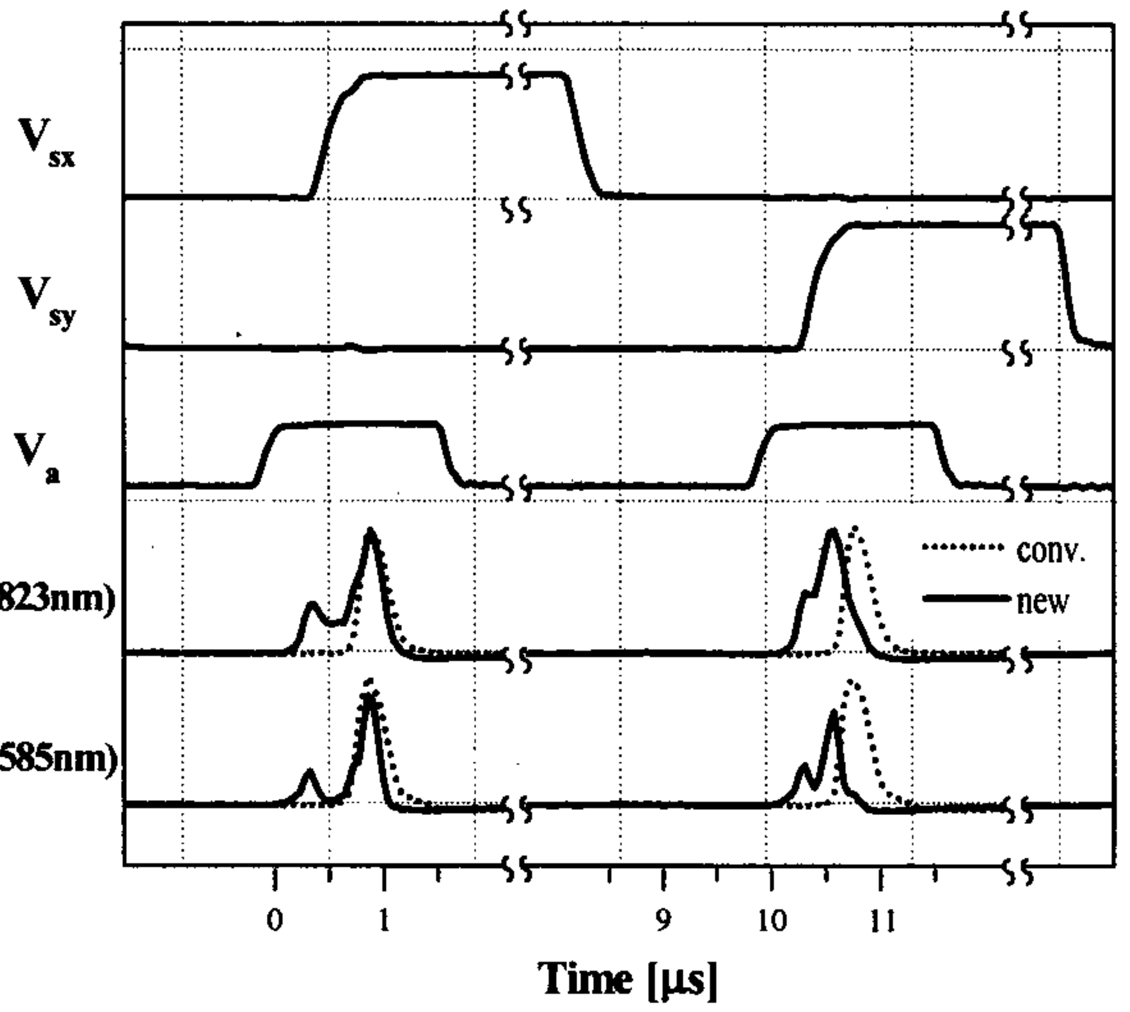


Fig. 2. Time-resolved emission spectra of IR (823 nm) and Ne (585 nm) measured from blue cells.

[1] Mode I : (i) ~ (v)

(i) V_{sx} : 0 V, V_{sy} : 0 V, V_a : -90 V

As shown in Fig. 4-(i), excessive wall charges were accumulated between the sustain electrodes, X and Y, and the address electrode, A, due to the abrupt transition of the previous auxiliary negative pulse from the base level of 0 V to the negative level of -90 V.

(ii) V_{sx} : 0 V, V_{sy} : 0 V, V_a : -90 V → 0 V

Then, when the auxiliary pulse jumped abruptly from the negative level of -90 V to the base level of 0 V prior to the application of the sustain pulse V_{sx}, a self-erasing discharge was produced due to the excessive wall charges between the sustain electrodes and the address electrode, as shown in Fig. 4-(ii). This discharge was triggered by the abrupt change in the negative pulse from -90 V to 0 V and erased some of the wall charges. As such, this discharge can be described as a kind of self-erasing discharge, since it is produced when all the voltages applied to the three electrodes are set at zero [3]. The priming particles, such as space charges, necessary for the subsequent sustaining discharge can be produced through this self-erasing discharge.

(iii-1, 2) V_{sx} : 0 V → 170 V, V_{sy} : 0 V, V_a : 0 V

When the sustain pulse V_{sx} was applied to the sustain electrodes during an auxiliary negative pulse at the base level of 0 V, a few priming particles remained within the cell, as indicated in Fig. 4-(iii-1). Thus, the main discharge was only produced when the sustain voltage was greater than a certain level, as indicated in Fig. 4-(iii-2). As mentioned in Fig. 4-(ii), the self-erasing discharge produced prior to the main discharge can create space charges. These space charges can then participate in the subsequent main discharge as priming particles if the time interval between the self-erasing discharge and the main discharge is very short [4]. Since the time interval in the current case was

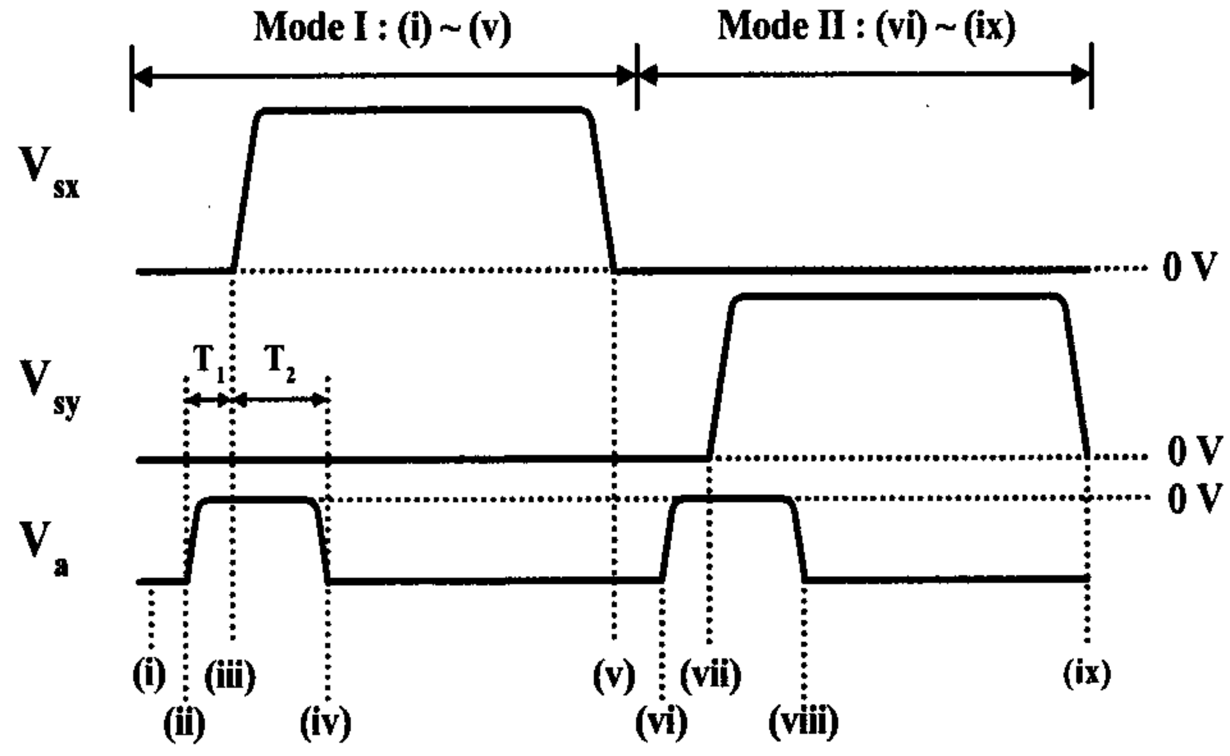


Fig. 3. Schematic diagram of sustain pulses employed to analyze Ne reduction mechanism.

very short (0.5 μs), the self-erasing discharge triggered by the negative pulse did play a role in providing priming particles to the subsequent sustaining discharge. However, it would appear that the number of priming particles was not large because the self-erasing discharge intensity was relatively weak. Accordingly, since only a small amount of priming particles were produced, the main discharge was produced under relatively strong electric field conditions, meaning that many electron-ion pairs were generated during the main discharge, as shown in Fig. 4-(iii-2).

(iii-3) V_{sx} : 170 V, V_{sy} : 0 V, V_a : 0 V

The wall charges accumulated on the sustain and address electrodes during the main discharge, thereby extinguishing the main discharge. However, some of the space charges still remained after the extinction of the main discharge.

(iv) V_{sx} : 170 V, V_{sy} : 0 V, V_a : 0 V $\rightarrow$ - 90 V

The application of the auxiliary negative pulse of -90 V to the address electrode A strengthened the electric field intensity between the sustain electrode X and the address electrode A. As a result, the conversion rate of the space charges into wall charges increased and a higher amount of wall charges were accumulated on the sustain electrode X and address electrode A from the space charges, as shown in Fig. 4-(iv).

(v) V_{sx} : 170 V $\rightarrow$ 0 V, V_{sy} : 0 V, V_a : - 90 V

In the current case, reducing the sustain pulse from 170 V to 0 V did not induce any additional discharge because the wall charges on the address electrode were captured by the negative pulse of -90 V. That is, the quantity of wall charges on the sustain electrodes was insufficient to make an additional discharge. Therefore, the wall charges remained almost constant.

[2] Mode Ⅱ : (vi) ~ (ix)

(vi) V_{sx} : 0 V, V_{sy} : 0, V_a: - 90 V $\rightarrow$ 0 V

In mode Ⅱ, the abrupt change of the auxiliary negative pulse from -90 V to 0 V induced a stronger self-erasing discharge than the previous self-erasing discharge in Fig. 4-(ii) in mode Ⅰ. As plotted in the measured IR peak in Fig. 2, the IR peak emitted during a self-erasing discharge in the sustain pulse V_{sy} was higher than that in the sustain pulse V_{sx}, which confirms the production of a strong self-erasing discharge in mode Ⅱ. This was presumably due to the accumulation of sufficient wall charges on the sustain electrode X and address electrode A based on lots of space charges produced by the previous strong main discharge.

(vii-1, 2) V_{sx} : 0 V, V_{sy} : 0 V $\rightarrow$ 170 V, V_a : 0 V

Unlike Fig. 4-(iii-1) in mode Ⅰ, when the sustain pulse V_{sy} at 170V was applied in the state of a zero address voltage, lots of priming particles remained within the cells due to the preceding strong self-erasing discharge. Thus, the main discharge was produced immediately after the self-erasing discharge, as illustrated in the main discharge curves where the IR and Ne emission were shifted to the left in the measured waveforms in Fig. 2. A large amount of priming particles, such as electrons and ions, required to fire the next main discharge were introduced near the gap between the sustain electrodes, X and Y, thereby contributing to the attenuation of both the firing voltage and the time lag for firing [5]. A Ne emission at 585 nm is generated from the excited state of 3p' $[1/2]_0$ (18.96 eV) [6], while VUV at 147 nm and 173 nm is generated from resonant state Xe_r^* (8.44 eV) and metastable state Xe_m^* (8.32 eV), respectively [7]. Since the energy state of Ne (3p'$[1/2]_0$) is relatively high, a stronger electric field is needed to produce an Ne emission. However, in the current case, the main discharge was effectively produced in a relatively lower electric field due to the sufficiency of priming particles. The intensity of the Ne emission during the main discharge was reduced considerably, as shown in Fig. 2. Meanwhile, as the energy state of Xe_r^* and Xe_m^* was relatively low, a large amount of space charges due to the priming effect excited Xe into Xe_r^* and Xe_m^* respectively. Consequently, due to the priming particles, the Ne emission intensity was significantly decreased, yet the IR intensity remained almost constant

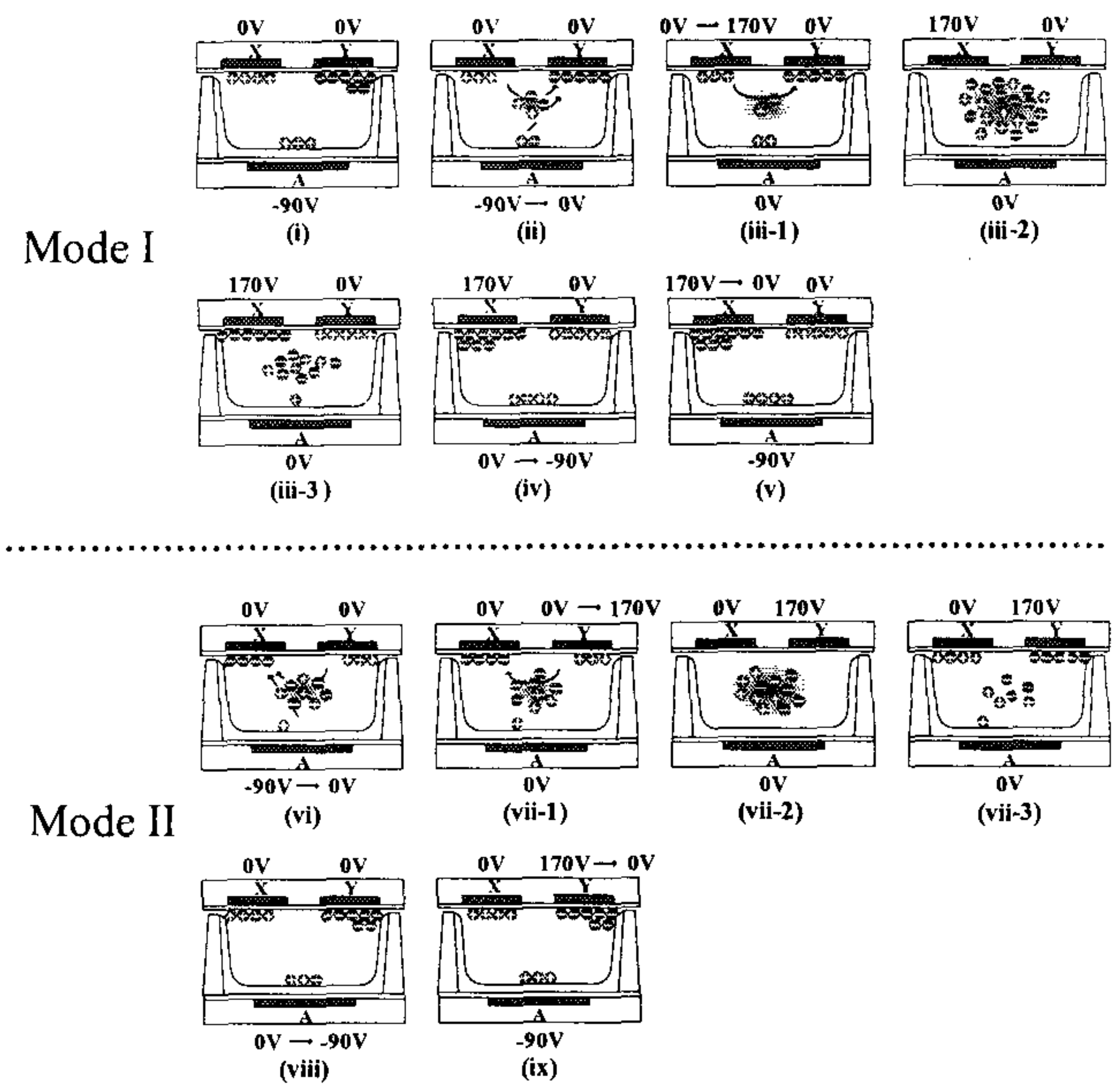


Fig. 4. Temporal behavior of wall/space charges within the cell.

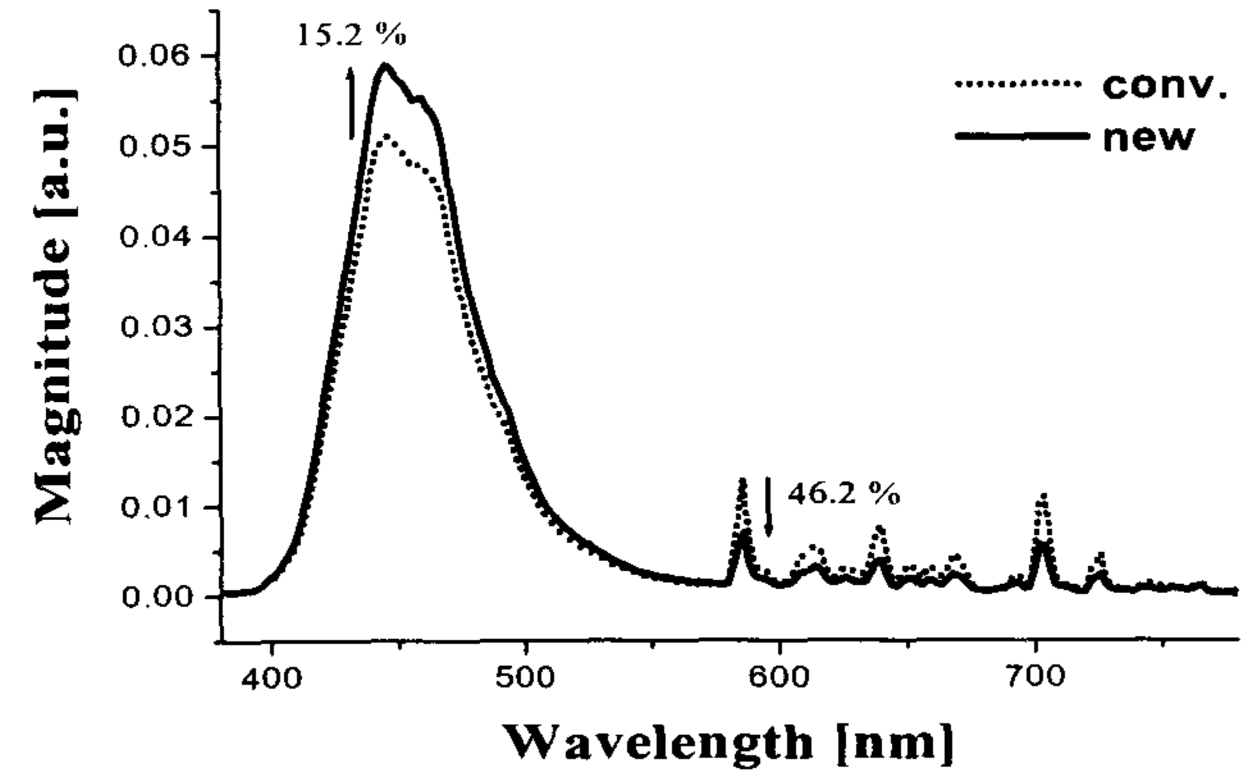


Fig.5. Variation in emission spectra for blue lights.

under a weak main discharge condition. This weak main discharge in mode II was maintained for hundreds of nanoseconds under a relatively low electric field condition.

(vii-3) V_{sx} : 0 V, V_{sy} : 170 V, V_a : 0 V

In the case of the presence of many priming particles, a weak electric field can contribute to enhancing the excitation of He-Ne-Xe gas instead of the ionization of He-Ne-Xe gas. Hence, the amount of wall charges accumulated on the sustain and address electrodes during a main discharge was relatively small due to the low ionization rate. Thereafter, the space charge remaining after the extinction of the main discharge was also small, as shown in Fig. 4-(vii-3).

(viii) V_{sx} : 0 V, V_{sy} : 170 V, V_a : 0 V → - 90 V

In the current case, the application of the auxiliary negative pulse at -90 V did not contribute much to the additional accumulation of wall charges due to the small amount of space charges when compared with Fig. 4-(iv), as illustrated in Fig. 4-(viii). As such, the intensity of the subsequent self-erasing discharge produced by the abrupt change in the auxiliary negative pulse from -90 V to 0 V was weak due to the small amount of accumulated wall charges, as described in Fig. 4-(ii). Since this weak self-erasing discharge only produced a small amount of space charges, when the main discharge was initiated, only a few priming particles remained, thus the main discharge was produced under a relatively high electric field condition, as illustrated in Fig. 4-(iii-1, 2).

(ix) V_{sx} : 0 V, V_{sy} : 170 V → 0 V, V_a : -90 V

As in the case of Fig. 4-(v), reducing the sustain pulse V_{sy} from 170 V to 0 V did not induce any additional discharge because the wall charges on the address electrode were captured by the negative pulse at -90 V. Therefore, the wall charges remained almost constant.

Fig. 5 shows the variations in the emission spectra for blue lights in the case of applying the new auxiliary negative pulse relative to a conventional driving pulse with no negative pulse. For the auxiliary negative pulse, the amplitude was -90 V and the pulse widths T_1 and T_2 were 0.5 μs and 1.0 μs, respectively. The Ne emission intensity decreased by about 46.2 %, verifying that the Ne emission in the blue cells was reduced considerably. The blue luminance also increased slightly from 385 cd/m^2 to 390 cd/m^2. As a result, when the new auxiliary negative pulse was applied, the color gamut area was expanded by about 9.2 %, as shown in the CIE Chromaticity Diagram (1931) in Fig. 6. Accordingly, the experimental results confirmed that the auxiliary negative pulse could improve the color purity by selectively reducing the Ne emission intensity in a PDP filled with a He-Ne-Xe mixture gas.

IV. CONCLUSION

The current paper proposed a new driving scheme for reducing Ne emission. The new driving scheme due to the new auxiliary pulse can significantly reduce the Ne emission without causing any loss in luminance. The reduction of Ne emission can be explained based on the priming effect between the main discharge and the self-erasing discharge triggered by the new auxiliary negative pulse. As a result, the color gamut area is expanded by approximately 9.2 % in comparison with the conventional case. It is expected that this new driving will contribute to improving the color purity of an AC PDP by reducing the Ne emission.

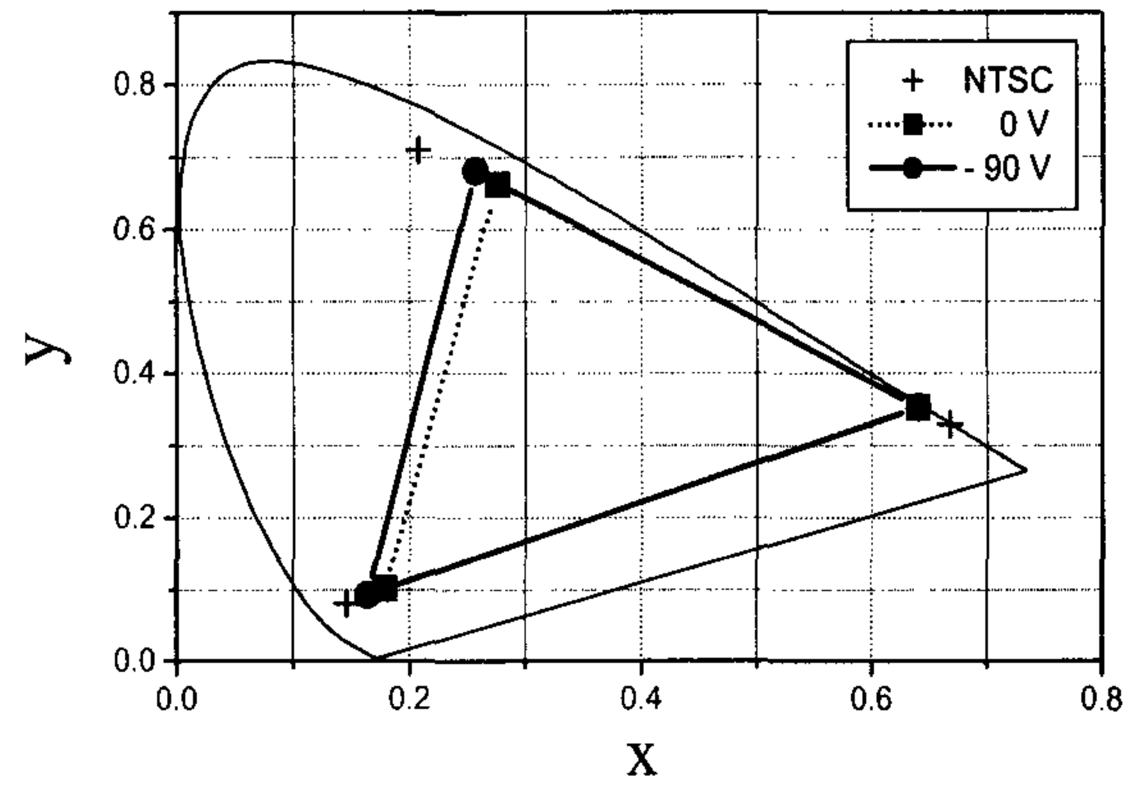


Fig. 6. Enlargement of color gamut area.

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