Study on Discharge Stability of Cost-Effective Driving Method Based on V_t Close-Curve Analysis in AC Plasma-Display Panel

Byung-Gwon Cho, Heung-Sik Tae, *Senior Member, IEEE*, Kazuhiro Ito, Nam-Sung Jung, and Kwang-Sik Lee

***Abstract*—A new cost-effective driving method that can drive plasma-display panel cells without applying any driving waveform to the common electrode is proposed based on a V_t close-curve analysis. In this driving method, it is very important to prevent a misfiring discharge due to the inversion of the polarity of the wall charges accumulated between the scan and address electrodes. The measured V_t close-curve showed that a misfiring discharge caused by the polarity inversion phenomenon of the wall charges on the scan and address electrode could be prevented by minimizing the potential difference between the scan and address electrodes by applying a positive auxiliary pulse to the address electrode, especially while applying the positive sustain pulse during a sustain period. As a result, the proposed cost-effective driving method can reduce the driving cost by about 20% through eliminating the common driving board and successfully display various image patterns, such as the white, red, green, and blue patterns, on a 42-in plasma television without any misfiring discharge.**

***Index Terms*—AC plasma-display panel (PDP), cost-effective driving method, V_t close-curve.**

I. Introduction

PLASMA TELEVISIONs (TVs) are considered the most promising candidate for digital TV due to such conspicuous features as a slim-type large area (> 40 in), self-emitting-based good color-reproduction capability, wide-dynamic-contrast ratio, and fast visible-conversion response (few microseconds) by the phosphor layer per sustain pulse [1]. Thus, to capture the TV consumer market and maintain a lead over other flat panel display devices, the development of a low-cost driving technology for plasma TVs has become a critical issue. Most recent efforts have focused on reducing the address voltage [2], a single-scan method [3], and decreasing the number of electrical parts. However, if the millions of plasma-display panel (PDP) cells could be driven by applying the driving waveforms to only the scan and address electrodes without applying any driving waveform to the common electrode, the driving cost could be considerably reduced due to the elimination of the common driving board alone. Some research in this area has already been reported [4]. Yet, since the millions of PDP cells are driven based on a precise control of the wall charges accumulating on the three electrodes, such a driving method inherently causes the serious problem of a misfiring discharge, as the common electrode must remain grounded throughout the reset, address, and sustain periods, unlike the conventional driving method in which the driving waveforms are applied to all three electrodes throughout the reset, address, and sustain periods. When comparing the difference between the two driving methods, the alternating application of the driving waveform to the common and scan electrodes can be replaced by applying the driving waveform just to the scan electrode based on considering the potential difference between the common and scan electrodes. If only the discharge phenomenon between the common and scan electrodes is considered, a driving waveform with both positive and negative polarities, which is determined by the potential difference between the common and scan electrodes, can maintain the same discharge phenomenon as that of the conventional driving waveforms, as the wall charge distributions accumulating on the common and scan electrodes are only determined by the potential difference between the common and scan electrodes. However, the application of the driving waveform just to the scan electrode alters the potential difference between the scan (or common) and address electrodes, even though it does not change the potential difference between the common and scan electrodes. As such, the resultant change in the wall charges accumulating on the address electrode induce the serious problem of a misfiring discharge during a sustain period, making it impossible to drive the millions of PDP cells. Consequently, for this type of driving method, it is very important to prevent a misfiring discharge due to changes in the wall charge distribution, especially on the address electrode.

Accordingly, this paper presents a new cost-effective driving method that can drive PDP cells without applying any driving waveform to the common electrode, which means that this driving method can drive the PDP cell without the X-driving board (hereinafter, this method is simply called the eliminating X-board (EX) driving method). In the proposed EX-driving method, the voltage threshold (V_t) close-curve [5], [6] method is used to analyze the changes in the wall voltage to prevent a misfiring discharge. In particular, the effect of the status of the wall charges after a reset discharge on the sustain discharge characteristics is extensively examined.

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TABLE I
SPECIFICATIONS OF 42-in AC-PDP USED IN THIS RESEARCH

Front panel		Rear panel	
Sustain bus width	110 μm	Address electrode width	150 μm
ITO width	360 μm	Barrier rib width	60 μm
ITO gap	85 μm	Barrier rib height	120 μm
Segmented square ITO		Closed square barrier rib	
Ne(93%)-Xe(7%) gas mixture			

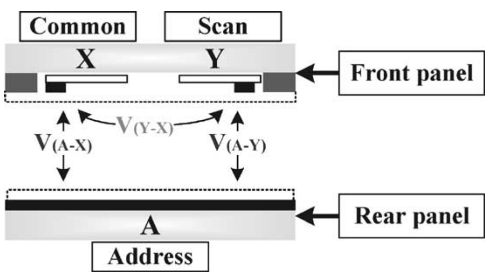


Fig. 1. Schematic diagram of the three-electrode-type PDP cell used in this research and voltage distribution among three electrodes, X, Y, and A, where potential difference between Y and X electrodes is $V_{(Y-X)}(=V_Y-V_X)$, potential difference between A and X electrodes is $V_{(A-X)}(=V_A-V_X)$, and potential difference between A and Y electrodes is $V_{(A-Y)}(=V_A-V_Y)$.

II. OPERATION PRINCIPLE OF PROPOSED EX-DRIVING METHOD

Table I shows the specifications of the 42-in ac-PDP employed in the current study, while Fig. 1 shows a schematic diagram of the three-electrode-type PDP cell used in this research and its voltage distribution among the three electrodes, X, Y, and A, where the potential difference between the common (X) and scan (Y) electrodes is $V_{(Y-X)}(=V_Y-V_X)$, the potential difference between the address (A) and common (X) electrodes is $V_{(A-X)}(=V_A-V_X)$, and the potential difference between the address (A) and scan (Y) electrodes is $V_{(A-Y)}(=V_A-V_Y)$.

Figs. 2(a) and (b) show the conventional and proposed EX-driving waveforms and corresponding potential differences, $V_{(Y-X)}$ and $V_{(A-Y)}$ in the conventional and proposed EX-driving waveforms, respectively. As shown in Fig. 2(b), the new driving waveform, V_y applied only to the Y electrode has both positive and negative polarities, and the resultant potential difference, $V_{(Y-X)}$ between the X and Y electrodes is the same as that of the conventional driving waveform in Fig. 2(a). However, the new potential difference between the A and Y electrodes, $V_{(A-Y)}$ is quite different from that of the conventional driving waveform, especially after the ramp-up period. The different potential difference, $V_{(A-Y)}$ between the A and Y electrodes, for both driving waveforms during the ramp-down period induces changes in the wall charges accumulating on the Y and A electrodes after the reset discharge, as shown in (i) of (c) and (d) in Fig. 2. That is, as shown in (i) of Fig. 2(c), the negative and positive wall charges are accumulated on the Y and A electrodes, respectively, after the conventional ramp-down period. In this case, the polarities of the wall charges between the Y and A electrodes are the same as those of the wall charges accumulated during the ramp-up period, because the value of $|V_{\rm nf1}|$ at the end of the ramp-down period is relatively small. Accordingly, when the two positive sustain pulses are alternately applied to the X and Y electrodes during a sustain period, as shown in (ii) and (iii) of (c) in Fig. 2, no misfiring discharge is produced in the OFF-cells with no address discharge, as the negative wall charges accumulating on the X or Y electrodes after the reset period can block the applied positive potential during the sustain period. Conversely, as shown in (i) of Fig. 2(d), the positive and negative wall charges are accumulated on the Y and A electrodes, respectively, after the EX ramp-down period. In this case, because the value of $|V_{\rm nf2}|$ at the end of the ramp-down period is much larger than that of $|V_{\rm nf1}|$, the polarities of the wall charges are exactly opposite to those of the wall charges accumulated during the ramp-up period. Consequently, when the positive sustain pulse during a sustain period is applied to the Y electrode, a misfiring discharge can be produced in the OFF-cells with no address discharge due to the presence of the positive wall charges accumulating on the Y electrode, as shown in (ii) of Fig. 2(d). However, when the negative sustain pulse during a sustain period is applied to the Y electrode, no misfiring discharge is produced in the OFF-cells with no address discharge due to the presence of the positive wall charges accumulating on the Y electrode, as shown in (iii) of Fig. 2(d). As such, this result implies that the inversion of the polarity of the wall charges accumulating between the Y and A electrodes after the reset period is the critical factor causing a misfiring discharge during the sustain period with the EX-driving method. For the manufacturing cost of the proposed driving circuit, the proposed EX-driving waveform requires the positive to negative high-voltage switching device during the sustain period because the sustain pulse has both positive and negative polarities. Thus, if the conventional FET device was used as a switching device to generate the positive and negative high-voltage pulses from the Y driving board, the switching device cost would be increased. However, in this experiment, the cheap insulated gate bipolar transistor (IGBT) device was used as a switching device instead of the FET device. Accordingly, thanks to the use of the IGBT as a switching device, the circuit cost for the proposed EX-driving method was reduced when compared with that for the conventional driving method.

III. RESULTS AND DISCUSSION

A. Analysis of Misfiring Discharge Using V_t Close-Curve With Proposed Ex-Driving Method

Fig. 3(a) shows the two different V_t close-curves on the applied voltage plane measured before and after the reset period when applying the conventional driving waveform in Fig. 2(a). The six sides of the V_t close-curve in Fig. 3(a) mean the threshold voltages, thus the inner region of the V_t close-curve in Fig. 3(a) means a nondischarge region, while the outer region means a discharge region [5]. In Fig. 3(a), the V_t close-curve measured before the reset period shows that the firing voltage V_{f1} was about 170 V for the MgO cathode condition (side II), whereas the firing voltage V_{f2} was about 250 V for the phosphor cathode condition (side V). As shown by the V_t

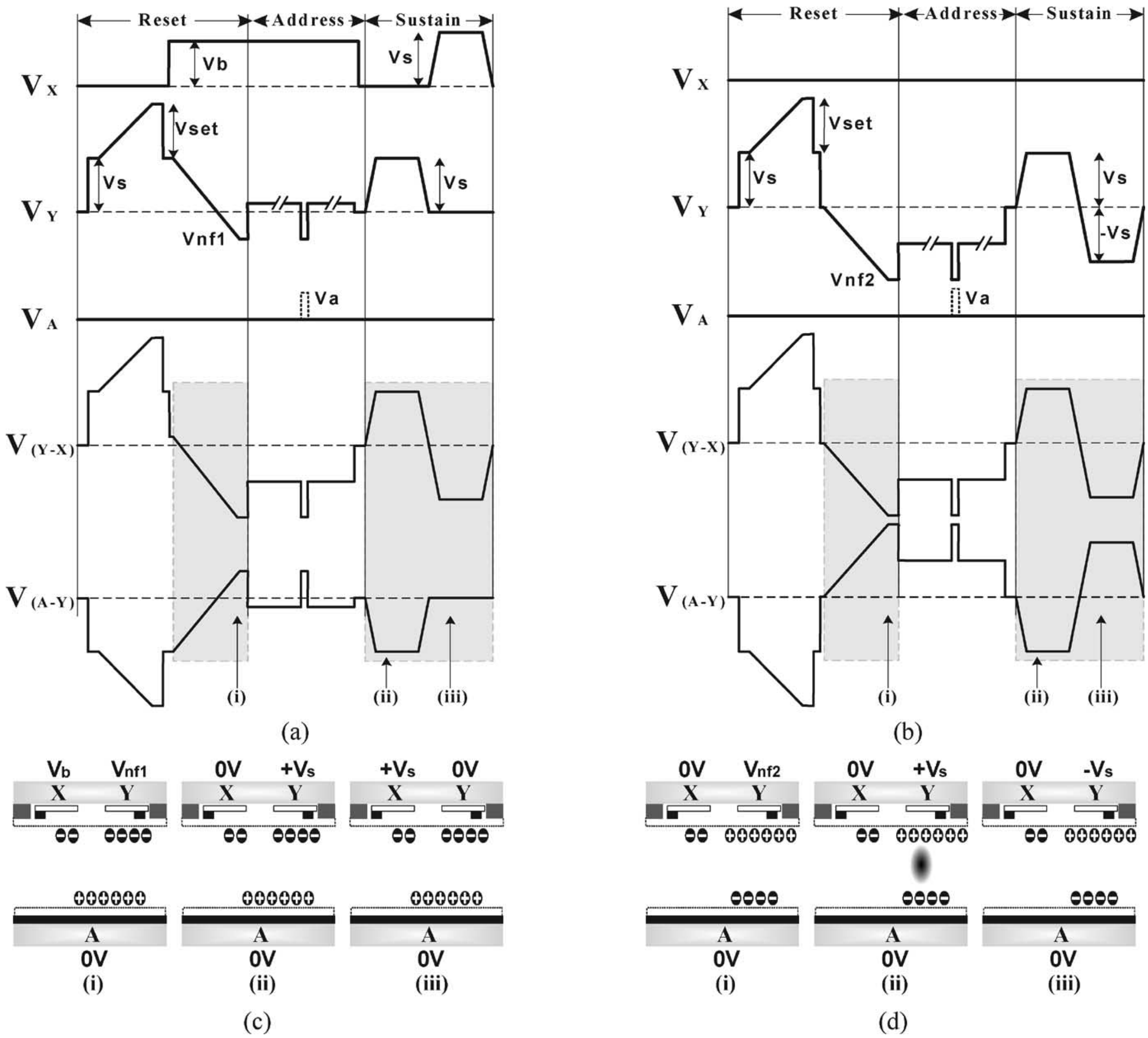


Fig. 2. Comparison of (a) conventional and (b) proposed EX-driving waveforms applied to three electrodes, X, Y, and A for OFF-cells in 42-in ac-PDP, including reset, address, and sustain periods and corresponding potential differences, $V_{(Y-X)}$ and $V_{(A-Y)}$ for (a) conventional and (b) proposed EX-driving waveforms, and temporal behavior of wall charges in (c) conventional and (d) proposed EX- driving waveforms. (a) Conventional driving waveforms. (b) Proposed EX-driving waveforms. (c) Temporal behavior of wall charges in (a). (d) Temporal behavior of wall charges in (b).

close-curves in Fig. 3(a) measured before and after the reset period, the discharge start threshold voltage between the X (or Y) and Y (or X) electrodes, $V_{tXY}(=\mathrm{I})$ (or $V_{tYX}=\mathrm{IV}$) was not changed, whereas the discharge start threshold voltage between the A (or Y) and Y (or A) electrodes, $V_{tAY}(=\mathrm{II})$ (or $V_{tYA}=\mathrm{V}$) was changed. Therefore, the V_t close-curves in Fig. 3(a) illustrate that the changes in the accumulating wall charges occurred predominantly between the Y and A electrodes through the reset discharge, resulting in changes in the threshold voltage between the Y and A electrodes. The horizontal axis for the applied voltage plane in Fig. 3(a) represents the potential difference, $V_{(X-Y)}(=V_X-V_Y)$ between the X and Y electrodes, whereas the vertical axis represents the potential difference, $V_{(A-Y)}(=V_A-V_Y)$ between the A and Y electrodes. Thus, when the positive sustain pulse of 170 V was only applied to the Y electrode, the potential difference, $V_{(X-Y)}[=V_X(0\ \mathrm{V})-V_Y(170\ \mathrm{V})]$ was -170 V, and the potential difference, $V_{(A-Y)}[=V_A(0\ \mathrm{V})-V_Y(170\ \mathrm{V})]$ was also -170 V. As such, the resultant voltage vector, $V_S(Y)$ is the vector sum of $V_{(X-Y)}$ and $V_{(A-Y)}$, as shown in (1) in Fig. 3(a). Conversely, when the positive sustain pulse was only applied to the X electrode, the potential difference, $V_{(X-Y)}[=V_X(170\ \mathrm{V})-V_Y(0\ \mathrm{V})]$ was 170 V, and the potential difference, $V_{(A-Y)}[=V_A(0\ \mathrm{V})-V_Y(0\ \mathrm{V})]$ was 0 V. Therefore, the resultant voltage vector, $V_S(X)$ was located on the horizontal axis, as shown in (2) in Fig. 3(a). In this case, in the OFF-cells with no address discharge, no misfiring discharge was induced during a sustain period, because the sustain voltage vectors, $V_s(X)$ and $V_s(Y)$ was only moved within the threshold voltage plane, i.e., the V_t close-curve, as shown in Fig. 3(a). In contrast, as mentioned previously, a misfiring discharge easily occurred during a sustain period when applying the EX-driving waveform in Fig. 2(b). To analyze the cause of the misfiring discharge induced when applying the driving waveforms in Fig. 2(b), the V_t close-curve was measured after the reset period and the results given in Fig. 3(b). In the conventional case of Fig. 3(a), the V_t close-curve after the reset period shifted lower, whereas in the EX-driving case in Fig. 3(b), the V_t

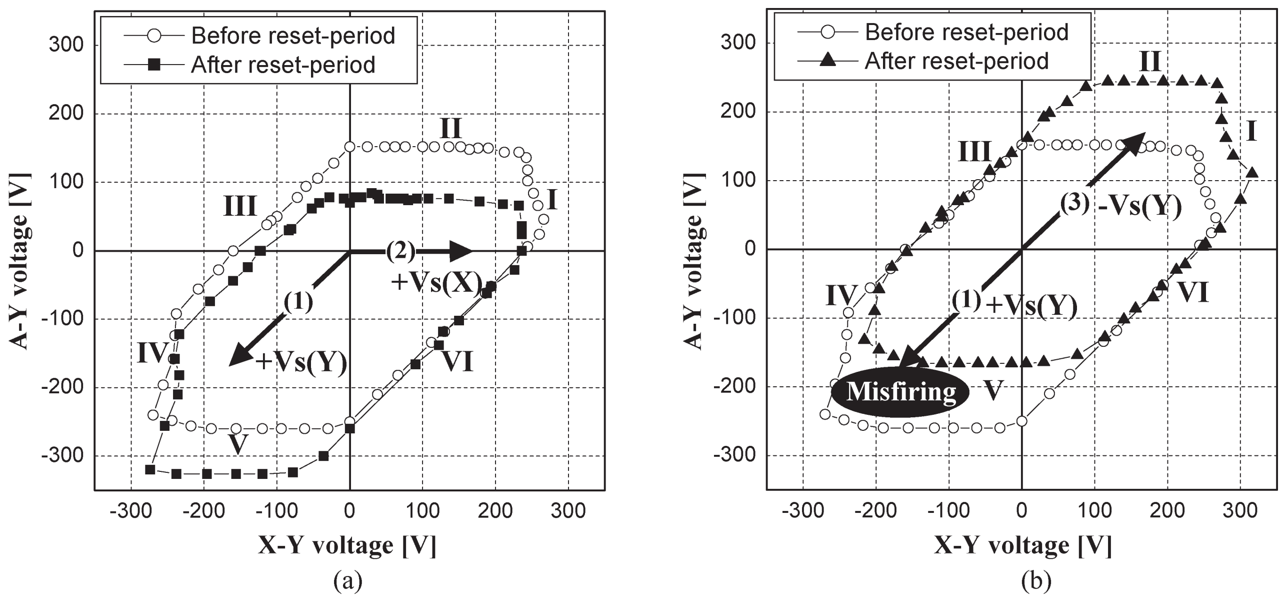


Fig. 3. (a) V_t close-curves on applied voltage plane measured before and after reset period when applying conventional driving waveform in Fig. 2(a), and (b) V_t close-curves on applied voltage plane measured after reset period to analyze cause of misfiring discharge induced when applying proposed EX-driving waveforms in Fig. 2(b), where I: V_{tXY} (= Discharge start threshold voltage between X and Y), II: V_{tAY} (= Discharge start threshold voltage between A and Y), III: V_{tAX} (= Discharge start threshold voltage between A and X), IV: V_{tYX} (= Discharge start threshold voltage between Y and X), V: V_{tYA} (= Discharge start threshold voltage between Y and A), and VI: V_{tXA} (= Discharge start threshold voltage between Y and A).

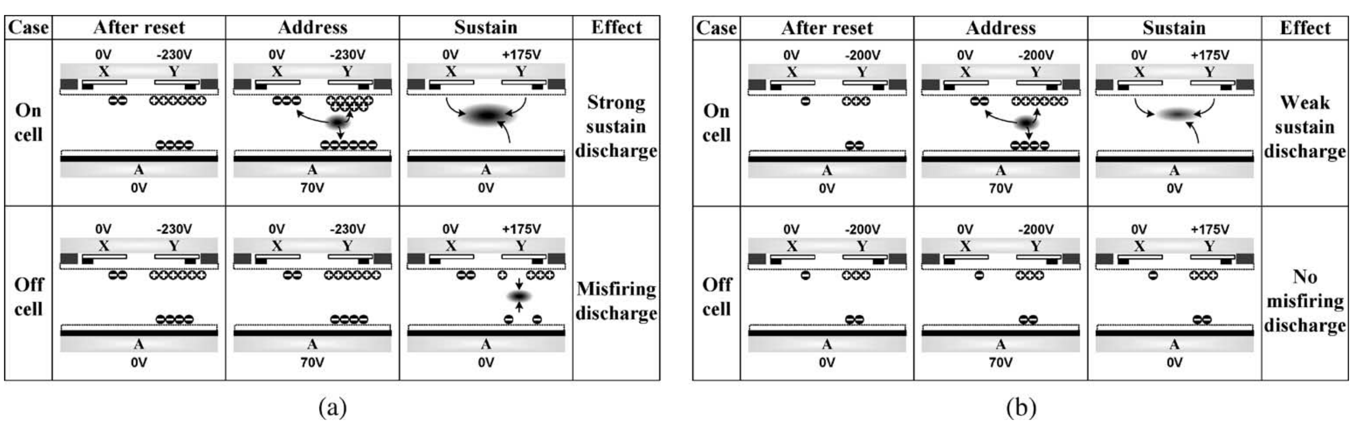


Fig. 4. Schematic wall charge model in each cell state when (a) $|V_{\mathrm{nf2}}| \geq |V_b - V_{\mathrm{nf1}}|$ and (b) $|V_{\mathrm{nf2}}| < |V_b - V_{\mathrm{nf1}}|$.

close-curve after the reset period shifted upwards, meaning that the polarity of the wall charges accumulating between the Y and A electrodes with the EX-driving method was exactly opposite to that with the conventional driving method. This inversion of the polarity of the wall charges with the EX-driving method is mainly due to the lower negative falling voltage, $V_{\mathrm{nf2}}(\ll V_{\mathrm{nf1}})$ in Fig. 2(b). Consequently, unlike the conventional sustain waveforms in Fig. 2(a), when the sustain pulse with both positive $(+V_s)$ and negative $(-V_s)$ amplitudes was alternately applied to only the Y electrode, the sustain voltage vectors were moved, as shown in (1) and (3) in Fig. 3(b). The V_t close-curve measurement result in Fig. 3(b) confirmed that the positive sustain voltage $(+V_s)$ applied during a sustain period induced a misfiring discharge, which is, the applied voltage resulting from the application of the positive sustain voltage $(+V_s)$ exceeded one side $(V_{tYA}$: V) of the V_t close-curve, which means that a misfiring discharge was produced between the Y and A electrodes. In this case, the shape of the V_t close-curve after the reset period depended strongly on the value of the negative falling voltage, V_{nf2} in Fig. 2(b). Consequently, it was important to investigate the effects of the voltage level of V_{nf2} on the sustain discharge characteristics, including a misfiring discharge. When the voltage level of $|V_{\mathrm{nf2}}|$ in Fig. 2(b) was greater than the voltage level of $|V_b - V_{\mathrm{nf1}}|$ in Fig. 2(a) (for example, $|V_{\mathrm{nf2}}| = -230$ V), as shown in the ON-cell in Fi g. 4(a), more wall charges were accumulated on the three electrodes due to the high-potential difference among the three electrodes. In particular, positive and negative wall charges were accumulated on the Y and A electrodes after the reset discharge, respectively. In this case, the polarities of the accumulated wall charge were exactly opposite to those of the accumulated wall charges after the conventional reset discharge. Despite the inversion polarity of the wall charges, a highly negative scan voltage, such as -230 V, was able to

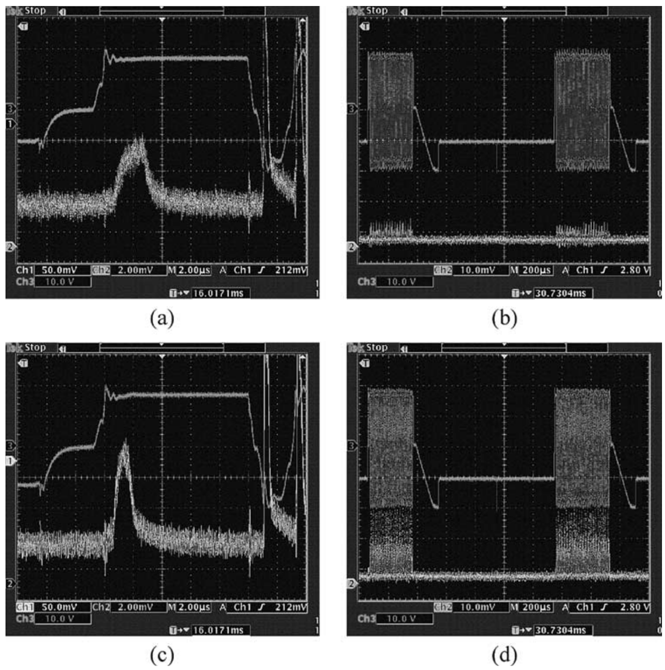


Fig. 5. IR waveforms emitted during first sustain discharge and sustain period for ON-cells at different voltage levels of $V_{\rm nf2}(= V_{\rm sc2})$ in Fig. 2(b): (a) and (b): $V_{\rm nf2} = -200$ V, and (c) and (d): $V_{\rm nf2} = -230$ V. (a) First sustain at $V_{\rm nf2} = -200$ V. (b) Sustain period at $V_{\rm nf2} = -200$ V. (c) First sustain at $V_{\rm nf2} = -230$ V. (d) Sustain period at $V_{\rm nf2} = -230$ V.

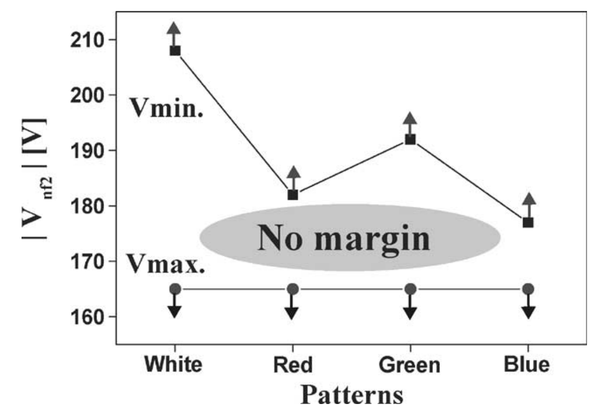
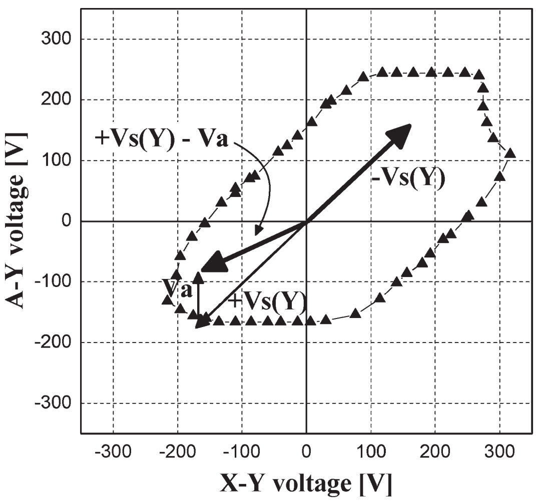


Fig. 6. Voltage margins relative to variation in voltage level of $|V_{\rm nf2}|$ for various image patterns, such as white, red, green, and blue images, on 42-in ac-PDP when applying proposed EX-driving waveform in Fig. 2(b).

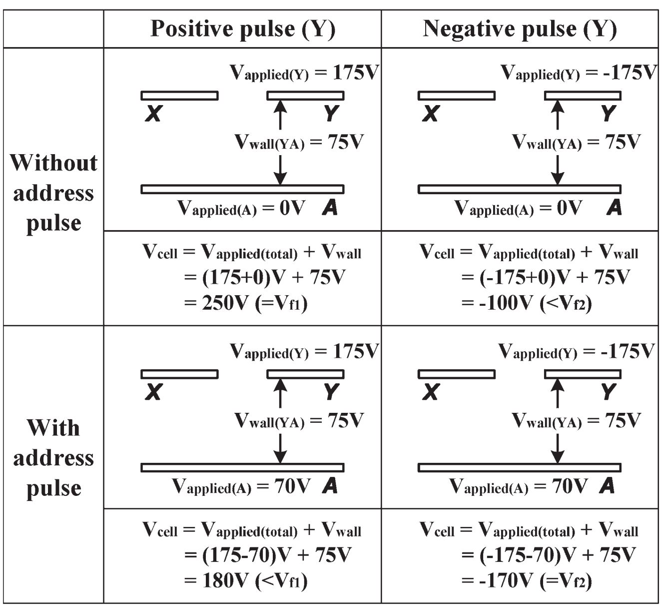
produce a stable address discharge during an address period, as shown in the ON-cell in Fig. 4(a). However, for the OFF-cells with no address discharge, the many accumulated wall charges with an opposite polarity to the conventional case, i.e., positive polarity on the Y electrode and negative polarity on the A electrode, inevitably induced a misfiring discharge when the positive pulse was applied to the Y electrode, as shown in the OFF-cell in Fig. 4(a). When the voltage level of $|V_{\rm nf2}|$ in Fig. 2(b) was less than the voltage level of $|V_b - V_{\rm nf1}|$ in Fig. 2(a) (for example, $|V_{\rm nf2}| = -200$ V), a misfiring discharge was prevented as only a few wall charges were accumulated on the three electrodes, despite their inversion polarities, when the positive pulse was applied to the Y electrode, as shown in the OFF-cell in Fig. 4(b). However, for the ON-cells, only a small amount of wall charges were accumulated after the address discharge due to the low-potential difference between the X and Y electrodes, and between the A and Y electrodes, resulting in a weak sustain discharge, as shown in the ON-cell in Fig. 4(b). The corresponding experimental results are shown in Fig. 5(a)–(d). Fig. 5 illustrates the changes in the IR emission intensities during the first sustain discharges [(a) and (c)] and sustain periods [(b) and (d)] at different voltage levels of $V_{\rm nf2}$, where $V_{\rm nf2}$ was -200 V in (a) and (b), and -230 V in (c) and (d). The first sustain discharge was observed to be faster and stronger in the case of $V_{\rm nf2} = -230$ V than $V_{\rm nf2} = -200$ V, as mentioned in Fig. 4. The resultant sustain discharge during the sustain period was also observed to be strong and stable in the case of $V_{\rm nf2} = -230$ V, as shown in Fig. 5(d). Fig. 6 shows the voltage margins relative to the variations in the voltage level of $|V_{\rm nf2}|$ for various image patterns, such as white, red, green, and blue images, on the 42-in ac-PDP when applying the proposed EX-driving waveform in Fig. 2(b). In Fig. 6, the value of $V_{\min}$ means the voltage level of $|V_{\rm nf2}|$ at which all the cells in the 42-in panel were turned on, whereas the value of $V_{\max}$ means the voltage level of $|V_{\rm nf2}|$ at which a misfiring discharge began to be produced in the 42-in panel. Unlike the typical case, $V_{\min}$ was higher than the $V_{\max}$, meaning that there was no margin for the proposed EX- driving waveform in Fig. 2(b). That is, when the voltage level of $|V_{\rm nf2}|$ was increased, a misfiring discharge was produced ($V_{\max}$ case), whereas when the voltage level of $|V_{\rm nf2}|$ was decreased, the probability of a failed sustain discharge became higher due to a weak sustain discharge ($V_{\min}$ case). As explained in relation to Figs. 3(b), 4, and 6, it was very difficult to prevent a misfiring discharge in the case of adopting the EX-driving waveforms in Fig. 2(b) without any modification. Therefore, in the following section, a method of preventing a misfiring discharge when adopting the EX-driving waveforms of Fig. 2(b) is given and discussed based on a V_t close-curve analysis.

B. Proposed Driving Method for Preventing Misfiring Discharge Based on V_t Close-Curve Analysis

As seen in the V_t close-curve in Fig. 3(b), a misfiring discharge was produced in the OFF-cells when applying the positive sustain pulse to the Y electrode during the sustain period. Therefore, if a positive auxiliary pulse, V_a were also applied to the A electrode during the application of the positive sustain pulse, $V_s(Y)$ to reduce the potential difference between the Y and A electrodes, the resultant voltage vector $[= V_s(Y) - V_a]$ would remain within the V_t close-curve, i.e., the nondischarge region, as shown in Fig. 7(a). For the OFF-cells, a misfiring discharge is prevented depending on the voltage distributions among the three electrodes, as shown in Fig. 7(b). The wall charge distributions remained identical to those prior to the address period when the first sustain pulse was applied in a sustain period. The wall voltage between the Y and A electrodes prior to the address discharge could be roughly obtained from the difference in the voltages between the V_t close-curves before and after the reset period in Fig. 3(b). In this case, the wall voltage was about 75 V. Without applying



(a)



(b)

Fig. 7. Changes in sustain voltage vector when applying address pulse during application of positive sustain pulse in (a) V_t close-curve, and (b) changes in net applied voltage plus wall voltage during application of positive and negative sustain pulses without/with applying address pulse, where firing voltage V_{f1} is 250 V for phosphor-cathode condition, and firing voltage V_{f2} is 170 V for MgO-cathode condition.

the auxiliary pulse, when the positive sustain pulse of $+175$ V was applied to the Y electrode, the resultant net applied voltage plus the wall voltage $(= 75$ V$)$ between the Y and A electrode was 250 V, which was greater than the firing voltage between the Y and A electrodes. Consequently, a misfiring discharge was produced between the Y and A electrodes. However, with an auxiliary voltage of 70 V, when the positive sustain pulse of 175 V was applied to the Y electrode, the net applied voltage between the Y and A electrodes was reduced to 105 V due to the auxiliary voltage. Thus, the resultant applied voltage plus the wall voltage $(= 75$ V$)$ between the Y and A was only 180 V, which was less than the firing voltage between the Y and A electrodes, as the firing voltage V_{f1} between the Y and A electrodes was 250 V for the phosphor-cathode condition.

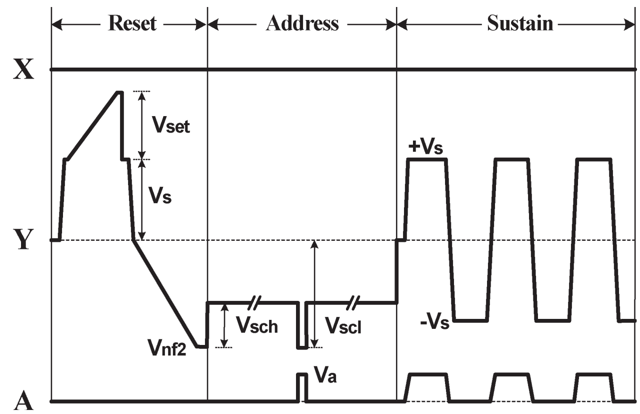


Fig. 8. Proposed EX-driving waveforms during reset, address, and sustain period without inducing any misfiring discharge.

Consequently, a misfiring discharge was not produced between the Y and A electrodes. As another example, when the negative pulse of -175 V was applied to the Y electrode without applying the auxiliary pulse, the resultant applied voltage plus the wall voltage $(= 75$ V$)$ between the Y and A electrode was -100 V, which was far less than the firing voltage between the Y and A electrodes. Thus, a misfiring discharge was not produced between the Y and A electrodes. However, with an auxiliary voltage of 70 V, when the negative sustain pulse of -175 V was applied to the Y electrode, the net applied voltage between the Y and A electrodes increased to -245 V. Thus, the resultant applied voltage plus the wall voltage $(= 75$ V$)$ between the Y and A electrodes was -170 V, exceeding the firing voltage, which was 170 V for the MgO-cathode condition.

Consequently, no misfiring discharge was produced between the Y and A electrodes. In contrast, with an auxiliary pulse of -70 V, a stable sustain discharge was produced without a misfiring discharge. However, in current PDP-circuit technology, the application of a negative auxiliary pulse to the A electrode is not used. Nonetheless, the results in Fig. 7 based on a V_t close-curve analysis demonstrate that minimizing the potential difference between the Y and A electrodes during the application of the sustain pulse, especially the positive sustain pulse, is an essential factor for preventing a misfiring discharge with the proposed EX-driving method.

Fig. 8 shows the proposed EX-driving waveforms for preventing a misfiring discharge by applying a positive auxiliary pulse to the A electrode only during the application of the positive sustain pulse during a sustain period. In Fig. 8, the amplitude of the positive auxiliary pulse during a sustain period was the same as that of the address pulse during an address period, while its width was the same as that of the positive sustain pulse. In particular, maintaining a constant positive voltage level for the auxiliary pulse during the application of the positive sustain pulse was very important for a stable sustain discharge. Fig. 9 shows the driving waveforms applied to the Y electrode and corresponding IR emission waveforms measured throughout the reset, address, and sustain periods when applying the proposed EX-driving waveforms in Fig. 8. As shown in the IR emission waveform in Fig. 9 measured

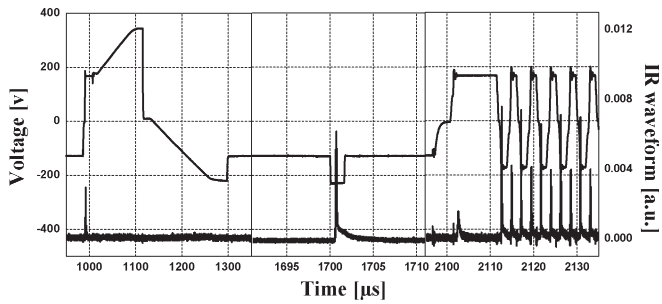


Fig. 9. Driving waveforms applied to Y electrode and corresponding IR emission waveforms measured throughout reset, address, and sustain periods when applying proposed EX-driving waveforms in Fig. 8.

throughout the reset, address, and sustain periods, the application of the positive auxiliary pulse lowered the $V_{\rm nf}(= V_{\rm scl})$ in Fig. 8, thereby producing a strong address discharge without a misfiring discharge. However, as shown in Fig. 9, the IR emission peak was higher during the negative sustain-pulsed period, whereas the IR emission peak was lower during the positive sustain-pulsed period. In the case of the lower IR peak during the positive sustain-pulsed period, its intensity was the same as that in the conventional case. Accordingly, the total amount of IR emission during the sustain-pulsed period was increased when applying the proposed EX-driving waveform in comparison with the conventional case. Nonetheless, the difference of the IR emission peak needs to be compensated. However, it was difficult to compensate the difference of the IR emission peak because the higher IR peak during the negative sustain-pulsed period is due to the participation in the sustain discharge of the positive wall charges accumulating on the phosphor layers. Consequently, further study needs to be made to compensate the asymmetric phenomenon of the IR emission peak due to the different two polarities of the proposed EX-driving sustain waveform. The validity of the proposed EX-driving waveform in Fig. 8 was also examined under various image patterns, such as white, red, and blue patterns, on the 42-in ac-PDP. Unlike the voltage margins in Fig. 6 under white, red, green, and blue images measured when applying the driving waveform in Fig. 2(b), stable margins were obtained when applying the waveforms in Fig. 8, as shown by the voltage margin data in Fig. 10. The suppression of a misfiring discharge due to the presence of the positive auxiliary pulse enabled a stable voltage margin, thereby allowing the millions of PDP cells in the 42-in ac-PDP to be driven, even in the case of the proposed EX-driving method. However, since the address pulses were applied during the positive-pulsed sustain period continuously, the lifetime problem about the address driver IC might be severe due to the current flow to the address driver IC. Thus, when applying the conventional and proposed driving waveforms to the 42-in PDP module, respectively, the address currents and the temperature rise in the tape carrier package (TCP) were measured. The experimental results are shown in Table II. As shown in Table II, the difference of the TCP temperature between the conventional and proposed driving waveforms was just 6.8 °C, meaning that the temperature rise was not high. Furthermore, the address current of 433 [mA] was not over the rated current range of the TCP, implying that even

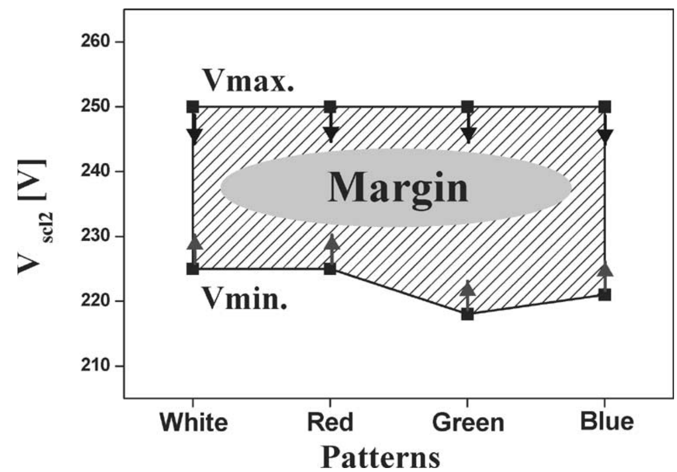


Fig. 10. Voltage margins relative to variation in voltage level of $|V_{\rm nf2}|$ for various image patterns, such as white, red, green, and blue images, on 42-in ac-PDP when applying driving waveform of case 1 in Fig. 8.

TABLE II
COMPARISON OF ADDRESS CURRENT AND TEMPERATURE RISE IN TCP

Driving Type / Measured Quantity	Conventional driving waveform	Proposed EX-driving waveform
Address current [mA]	50	433
TCP temperature [°C]	41	47.8

the current TCP could endure such an address current increase, even though the increasing value was not small. Nonetheless, the proposed EX-driving waveform would still cause a lifetime problem about the address driver IC, unless the robust and cheap address driver IC is newly developed. Therefore, further study needs to be made so as to find out another method to suppress the misfiring discharge when applying the proposed EX-driving waveform.

IV. CONCLUSION

A new cost-effective driving method that can drive millions of PDP cells without applying any driving waveform to the common electrode is proposed based on a V_t close-curve analysis. In this driving method, it is very important to prohibit a misfiring discharge due to the inversion of the polarity of the wall charges accumulating between the scan and address electrodes. The measured V_t close-curve showed that minimizing the potential difference between the scan and address electrodes by applying a positive auxiliary pulse to the scan electrode, especially during the application of the positive sustain pulse during a sustain period, could prevent a misfiring discharge caused by the polarity inversion phenomenon of the wall charges on the address electrode. As a result, the proposed cost-effective driving method can reduce the driving cost by about 20% through eliminating the common driving board and successfully display various image patterns, such as white, red, green, and blue patterns, on the 42-in plasma TV without any misfiring discharge.

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