Effects of Xe content on wall-voltage variation during address period in AC plasma-display panel

Soo-Kwan Jang
Choon-Sang Park
Heung-Sik Tae (SID Member)
Bhum Jae Shin (SID Member)
Jeong Hyun Seo (SID Member)
Eun-Young Jung

Abstract — To investigate the influence of the gas condition, especially xenon (Xe) gas, on the wall-voltage variation in relation to the electric-field intensity during the address period, the wall voltages were measured under various Xe-gas content ranging from 11 to 20% by using the V_t closed curve analysis method. It was observed that under a weak electric-field intensity between the scan and address electrodes, the change in Xe content did not affect the wall-voltage variation, even at a higher panel temperature of 65°C. However, under a strong electric-field intensity, the wall-voltage variations were reduced with an increase in the Xe content, confirming that a higher electric-field intensity would be required to induce the wall-voltage variation at a higher Xe content during the address period.

Keywords — *Wall-voltage variation, Xe-gas content, priming condition, electric-field intensity, panel temperature.*

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1 Introduction

The further improvement in the image quality in ACPDPs requires a wider driving margin and more stable reset and address discharge. A misfiring discharge at a high temperature was often observed, which was due to the failure of the address discharge at the upper-subfield and lower scans line, especially at a high-temperature condition. This is strongly related to the wall-voltage-variation phenomenon during the address period. The wall-voltage variations tended to increase with an increased number of applied address and sustain pulses, and these tendencies was intensified with an increase in temperature.[1,2] Nonetheless, the wall-voltage-variation phenomenon is still not well understood. In particular, the wall-voltage-variation phenomenon has not been investigated in relation to the electric-field intensity under various Xe gas contents.

In this paper, to investigate the wall-voltage variation in relation to the electric-field intensity during the address period under various Xe-gas conditions, the wall-voltage variations were examined relative to the Xe content ranging from 11 to 20% by adjusting the applied voltage between the scan and address electrodes, based on the V_t closed curve analysis. In order to stabilize the discharge, the reset and sustain waveforms were modified to be suitable for varying the Xe-gas content. The number of sustain pulses and the panel temperature were also varied in order to provide uniform priming conditions to the discharge cells for three different Xe-gas contents.

2 Experimental setup

The 42-in. test panel with a working gas pressure of 420 Torr was employed in the research, and its structure and dimensions were exactly the same as those of a conventional 42-in.-wide XGA-grade PDP with a box-type barrier rib. The gas mixtures used were He (50%)–Ne–Xe (11, 15, and 20%). The detailed panel specifications are listed in Table 1. The panel temperature of the test panel varied from –5 to +65°C by modifying the temperature of the glass of the rear panel with an external cooler and heater.

Figure 1 shows the V_t closed curves measured at three different Xe contents under a zero initial wall-voltage conditions. When the Xe-gas content was increased from 11 to 20%, the area of the V_t closed curve was enlarged, meaning that the firing voltages among the three electrodes increased in proportion to the Xe-gas content. In order to achieve a

TABLE 1 — Specification of 42-in. test panel employed in this study.

Pixel pitch	693 μm
Thickness of dielectric layer	30 μm
Rib height	120 μm
Address electrode width	90 μm
Pressure	420 Torr
ITO width	310 μm
ITO gap	60 μm
Gas mixture	He (50%)−Ne−Xe **(11%)** He (50%)−Ne−Xe **(15%)** He (50%)−Ne−Xe **(20%)**
Panel temperature	–5 ~ +65°C

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S-K. Jang, C-S. Park, and H-S. Tae are with the School of Electrical Engineering and Computer Science, Kyungpook National University, E10-911, 1370 Sankyuk-dong, Buk-gu, Daegu, NA 702-701, Korea; telephone +82-53-950-6563, e-mail: hstae@ee.knu.ac.kr.
B. J. Shin is with the Department of Electronics Engineering, Sejong University, Seoul, Korea.
J. H. Seo is with the Department of Electronics Engineering, University of Incheon, Incheon, Korea.
E-Y. Jung is with Core Technology Lab., Corporate R&D Center, Samsung SDI Co., Ltd., Gyonggi-do, Korea.

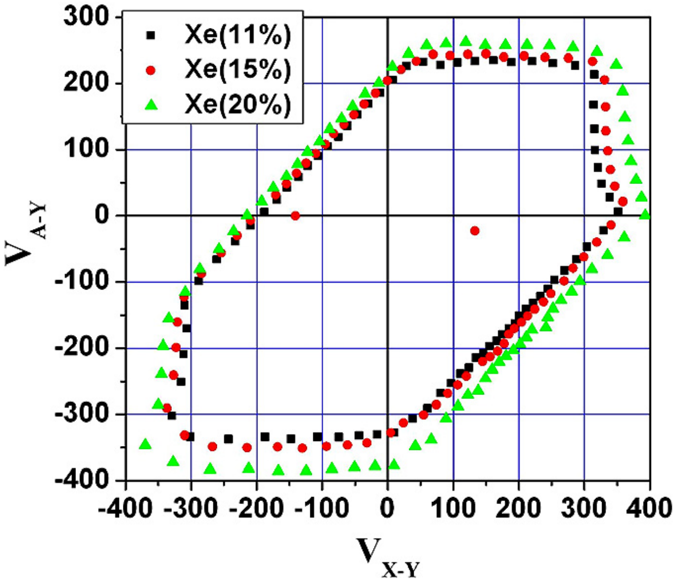

FIGURE 1 — Measured V_t closed curves for a 42-in. test panel relative to Xe-gas content.

stable discharge sequence, the applied voltage was adjusted for each of the gas mixtures used in this study.

Figure 2 shows the driving waveform employed for measuring the address-discharge delay properties due to changes in the panel temperature and the number of the applied sustain pulses. The applied sustain pulses were 10 pairs for the lower subfield (*i.e.,* SF 3), 50 pairs for the middle subfield (*i.e.,* SF 7), and 100 pairs for the upper subfield (*i.e.,* SF 10). To maintain the same wall-voltage condition after reset discharge, the different voltage levels of V_{NF} and V_B were applied during the reset period. To stabilize a sustain discharge, the different voltage levels of V_S were applied during the sustain period. The detailed values for V_{NF}, V_B, and V_S suitable for various Xe-gas contents are listed in Table 2.

Figure 3 shows the shifts of V_t closed curves after the reset discharge with respect to the reference V_t closed curve with a zero initial wall voltage at three different Xe-gas contents and room temperature of 25°C. In Fig. 3, the voltage

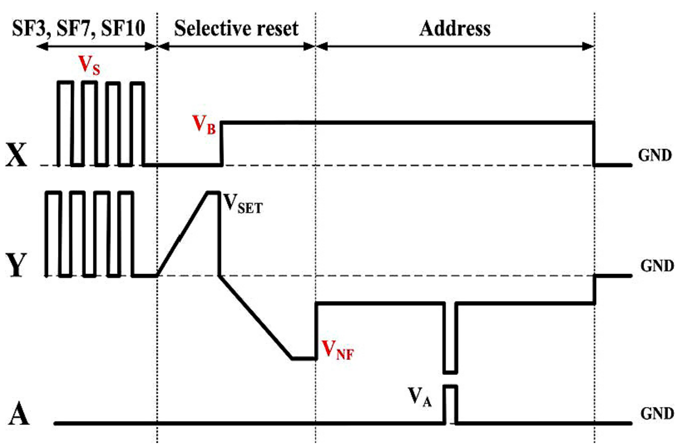

FIGURE 2 — Driving waveform employed for measuring address-discharge delay properties due to changes in the temperature and the number of sustain pulses.

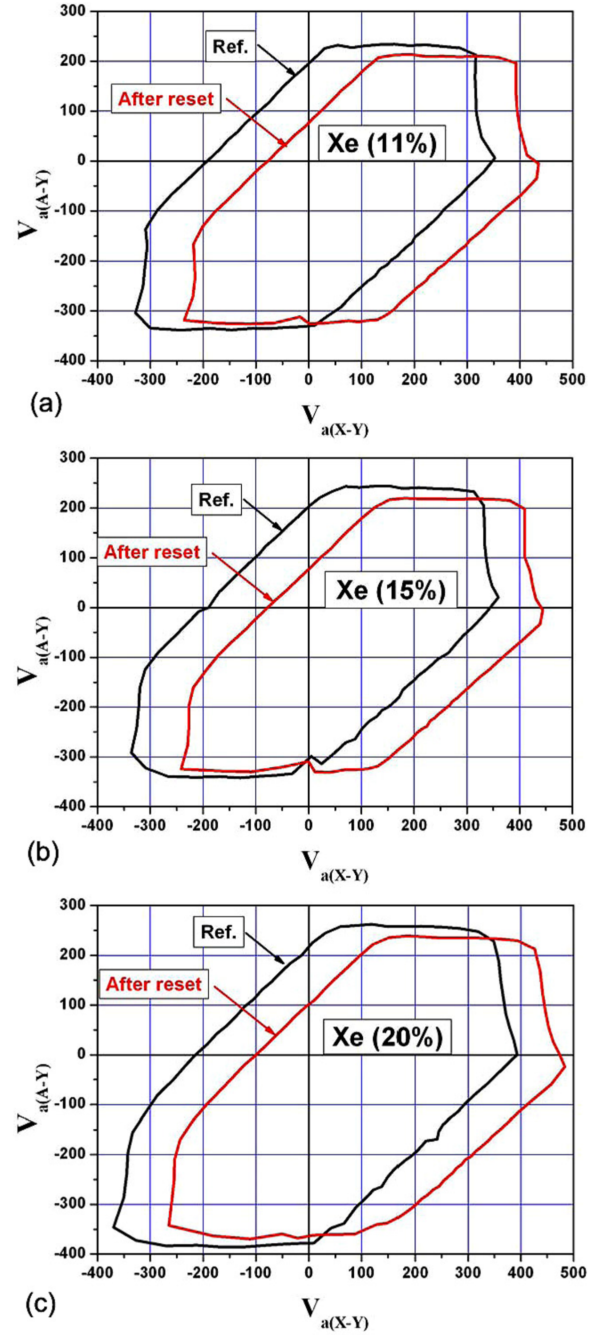

FIGURE 3 — Shifts of V_t closed curves after reset discharge with respect to reference V_t closed curve with zero initial wall voltage at three different Xe contents: (a) Xe (11%), (b) Xe (15%), and (c) Xe (20%).

difference between the shifted and reference V_t closed curves represents the final wall voltage induced by the wall charges formed during the reset discharge. The wall-voltage

TABLE 2 — Voltage levels of Fig. 2 suitable for various Xe-gas contents.

	Xe (11%)	Xe (15%)	Xe (20%)
V_{NF}	−165 V	−175 V	−190 V
V_B	75 V	80 V	95 V
V_S	200 V	205 V	210 V

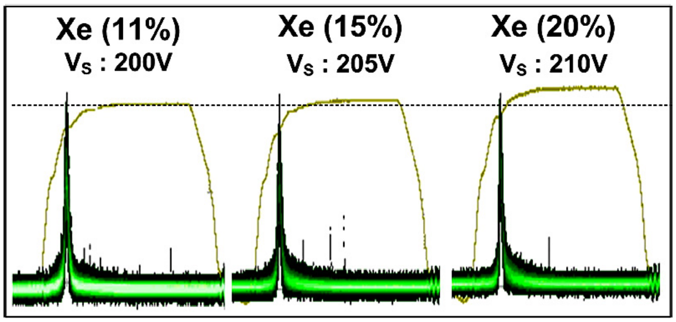

FIGURE 4 — IR (828 nm) intensities emitted during sustain discharge at three different Xe-gas contents.

condition after the reset discharge at each Xe-gas content was made to be similar by applying different voltage levels of V_{NF} and V_B, shown in Table 2.

Figure 4 shows the IR (828-nm) intensities emitted during the sustain discharge under three different Xe-gas contents. As shown in Fig. 4, the sustain-discharge intensities were observed to be almost the same regardless of the different Xe-gas contents by applying the sustain voltage levels suitable for various Xe-gas contents which are shown in Table 2.

3 Result and discussion

3.1 Uniform priming condition in discharge cells under various Xe-gas contents

It is very important to provide a uniform priming condition to the discharge cells for investigating the influence of the various Xe-gas contents on the wall-voltage variation in relation to the electric-field intensity during the address period. To establish the uniform priming conditions under three different Xe-gas contents, the panel temperature and the number of applied sustain pulses were adjusted in this experiment.

Figures 5(a) and 5(b) show the formative (t_f) and the statistical (t_s) delay times measured during the address discharge relative to (a) the panel temperature at SF3 and (b) the number of applied sustain pulses at a room temperature of 25°C, under various Xe-gas contents. As shown in Fig. 5(a), the t_f remained almost constant regardless of the panel temperature, but increased with an increase in the Xe-gas content, which is due to the increase in the firing voltage with Xe-gas content. This result indicates that the panel temperature has little influence on t_f because the wall-voltage condition is slightly changed relative to the panel temperature.[3] On the other hand, t_s decreased with an increase in the panel temperature, but showed a slight increase among the Xe-gas contents at a high panel temperature of 65°C. The increase in the panel temperature from –5 to +65°C causes the exo-electron emissions to be promoted from the MgO surface, which was presumably due to the thermal activation.[4] The emitted exo-electrons play a role in facilitating the initial discharge as priming particles. As a result, t_s decreased with panel temperature due to an increase in seed electrons, *i.e.*, priming particles in the dis-

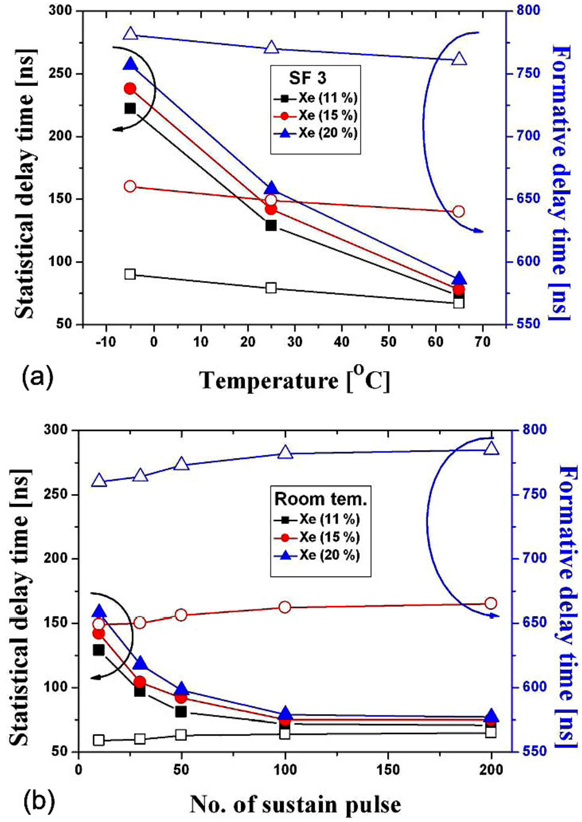

FIGURE 5 — Formative (t_f) and statistical (t_s) delay times measured during address discharge relative to (a) panel temperature at SF3 and (b) number of applied sustain pulse at 25°C, under various Xe-gas content.

charge cells. However, the difference in t_s among the Xe-gas contents was reduced in proportion to the panel temperature. In particular, at a high panel temperature of 65°C, an almost negligible difference in t_s was observed among the Xe-gas contents.[5,6] This means that, thanks to the active exo-electron emissions at a high panel temperature of 65°C, the priming particles are sufficiently provided to the discharge cells, even under different Xe-gas contents.

In the mean time, as shown in Fig. 5(b), when varying the number of applied sustain pulses from 10 to 200 pairs under various Xe-gas contents at a room temperature of 25°C, t_s was observed to decrease with an increase in the number of applied sustains pulses. However, t_f remained almost constant regardless of the number of applied sustain pulses. It is well known that the exo-electrons emitted from the MgO surface contribute to shortening t_s.[7] Accordingly, the decrease in the t_s in proportion to the number of the applied sustain pulses is strongly related to the exo-emission phenomenon of the MgO surface. The increase in the number of the sustain discharges means an increase in the electrons caught in the trap level of the MgO surface that can easily escape the shallow energy barrier.[8] Consequently, the increase in the number of sustain discharges results in an increase in the exo-electron emission. For a more than 100-pair sustain pulse, t_s remains almost constant regardless of the various Xe-gas contents, confirming that the priming particles are sufficiently provided to the discharge cells.

The experimental results of Figs. 5(a) and 5(b) confirmed that a panel temperature of 65°C and a 100-pair sustain pulse could establish a uniform priming condition so as to provide the sufficient seed electrons, *i.e.*, priming particles to the discharge cells regardless of the Xe-gas content. Under this experimental condition, *i.e.*, a panel temperature of 65°C and a 100-pair sustain pulse, the effects of the various Xe contents on the wall-voltage variation in relation to the electric-field intensity were examined during the address period.

3.2 Effects of Xe-gas content and electric-field intensity on wall-voltage variation during address period under uniform priming condition

Figure 6 shows the driving waveform employed for measuring the wall-voltage variation in relation to the electric-field intensity during the address period. The full-white V_A waveform was employed because it gave a greater wall-voltage variation during an address period than a full-black V_A waveform (all-zero address pulse). The width of the address pulses was 1.25 μsec, making the address periods 960 μsec for the 768th scan lines (*i.e.*, full-white pattern) due to the worst case pattern for the wall-voltage variation problem.[9] In Fig. 6, at the scan line prior to the last scan line, *i.e.*, 767th line, the wall-voltage variations during the address-period were measured using the V_t closed curve measurement technique[10] to investigate the influence of the electric-field intensity under different Xe-gas contents on the wall-voltage variation. The resultant address discharge was produced at the last scan line, *i.e.*, 768th line, in order to examine the influence of the wall-voltage variation on the address delay times. The voltage levels of V_{NF}, V_B, and V_S were the same as those in Table 2. To measure the wall-voltage variation in relation to the electric-field intensity between the address and scan electrodes, the voltage applied between the address (A) and scan (Y) electrodes was adjusted from 75 to 155 V by varying the voltage level of V_Y in Fig. 6 during the address period. As aforementioned,

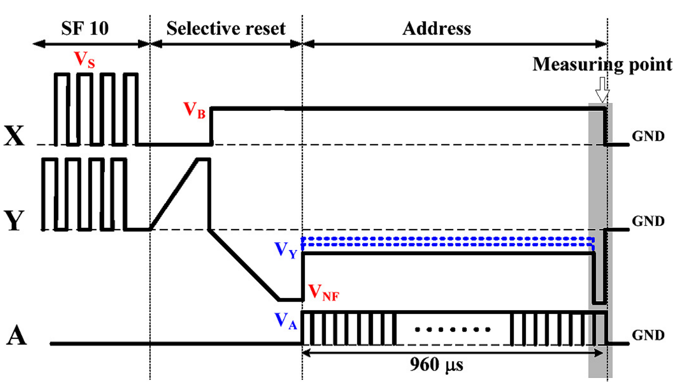

FIGURE 6 — Driving waveform employed for measuring wall-voltage variation in relation to electric-field intensity by varying $|V_Y|$ from 15 to 95 V during address period: SF 10, 65°C panel temperature.

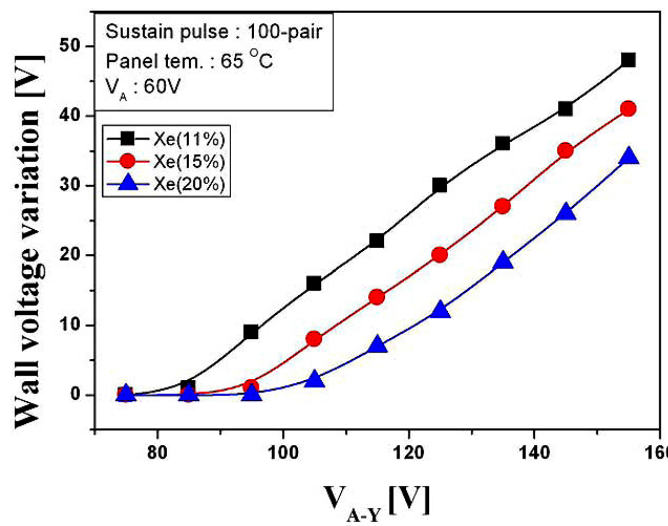

FIGURE 7 — Wall-voltage variation measured during address period relative to applied voltage between address-scan electrodes (= $V_{A\text{-}Y}$).

other conditions for providing the uniform priming condition were exactly the same as follows: the panel temperature was 65°C, the 100-pair sustain pulse was applied, and the applied voltage level of V_A was 60 V.

Figure 7 shows the wall-voltage variation measured during the address period relative to the applied voltage between the A-Y electrodes (= $V_{A\text{-}Y}$) at three different Xe-gas contents. As shown in Fig. 7, the three different Xe-gas contents showed different threshold voltages between the A-Y electrodes for inducing the wall-voltage variation, *i.e.*, 85 V for 11%–Xe, 95 V for 15%–Xe, and 105 V for 20%–Xe. Above the threshold voltage, the wall-voltage variations were increased in proportion to the applied voltage between the A-Y electrodes, implying that the electric-field intensity greater than the threshold intensity was related to the wall-voltage variation. The experimental result of Fig. 7 also showed that the high Xe-gas content required a high applied voltage (= $V_{A\text{-}Y}$) in order to induce the wall-voltage variation. When comparing the magnitude of the wall-voltage variation among the three different Xe-gas contents above the threshold-voltage condition, the wall-voltage variation was observed to decrease with an increase in the Xe-gas content. The wall-voltage variations could be induced as a result of the exo-electrons emitted from the MgO surface during the line-by-line scanning. In this case, the exo-electron emission should be independent of the gas condition such as Xe-gas content because the exo-electron emission characteristics depend only on the MgO surface states including the electrons captured in the trap-energy level of the MgO. However, our experiment shows that the wall-voltage variation strongly depends on the gas condition, especially Xe-gas content under the sufficient priming condition. The dependence of the Xe gas content on the wall-voltage variation postulates that a type of amplification induced by the exo-electron emission in the discharge space might be produced under a strong electric-field-intensity condition, thereby resulting in wall-voltage variation. However, a type

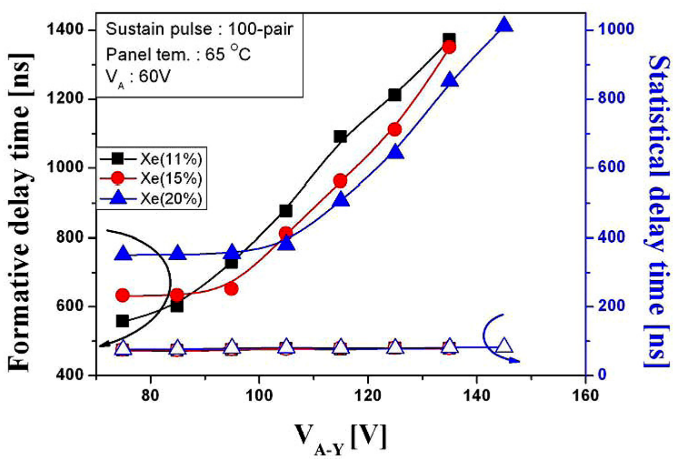

FIGURE 8 — Variation in t_f and t_s relative to applied voltage between address-scan electrodes (= $V_{A\text{-}Y}$).

of amplification in the discharge space was not directly observed. Thus, this point needs to be further investigated.

Figure 8 shows the variations in the formative (t_f) and statistical (t_s) delay times relative to the applied voltage between the A-Y electrodes (= $V_{A\text{-}Y}$) at three different Xe-gas contents. The t_s was observed to be almost constant regardless of the applied voltage between the A-Y electrodes (= $V_{A\text{-}Y}$) regardless of Xe gas content as a result of sufficiently providing the priming particles by raising the panel temperature and increasing the number of applied sustain pulses. This result indicates that t_s was observed to be almost independent of the electric-field intensity applied between the scan and address electrodes.

In the mean time, as shown in Fig. 7, under the weak-electric-field condition, *i.e.*, low voltage condition (= $V_{A\text{-}Y} <$ 95 V), the wall voltages varied only slightly. In this case, the t_f strongly depends not on the wall-voltage variation but the gas condition, meaning that the t_f becomes longer in proportion to the Xe-gas content due to the increase in the firing voltage with Xe-gas content. As shown in Fig. 8, the t_f was longer for higher Xe-gas content under weak electric-field conditions.

On the contrary, as shown in Fig. 7, under strong electric-field conditions, *i.e.*, high-voltage condition (= $V_{A\text{-}Y} >$ 100 V), the wall voltages varied significantly. In this case, t_f strongly depends on the wall-voltage variation as well as the gas condition. Because the wall-voltage variation was larger for the lower Xe-gas content, the resultant t_f was longer for the lower Xe-gas content under strong electric-field conditions.

4 Conclusion

Due to its importance for address-discharge stability, this paper investigated the wall-voltage variation in relation to the electric-field intensity during the address period under various Xe-gas conditions. The wall-voltage variations were examined relative to the Xe-gas content ranging from 11 to 20% by adjusting the voltages applied between the A-Y electrodes (= $V_{A\text{-}Y}$) during the line-by-line scanning prior the production of the address discharge at the last scan line. Experimental results showed that under a weak electric-field intensity between the scan and address electrodes during the address period, the change in the Xe-gas content did not affect the wall-voltage variation, even at a higher panel temperature of 65°C. In this case, the formative delay characteristics strongly depend on an increase in the firing voltage induced by the increase in the Xe-gas content. However, under a strong electric-field intensity, the wall-voltage variations were reduced with an increase in the Xe-gas content, confirming that the higher electric-field intensity would be required to induce the wall-voltage variation at a higher Xe-gas content during the address period. In this case, the formative delay characteristics strongly depended on the wall-voltage variation as well as the gas condition.

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Soo-Kwan Jang received his B.S., M.S., and Ph.D. degrees in electronic and electrical engineering from Kyungpook National University, Daegu, Korea, in 2003, 2005, and 2010, respectively. Since 2010, he has been a Post-Doctoral Fellow at the School of Electrical Engineering and Computer Science, Kyungpook National University. His current research interests include plasma physics and driving waveforms for plasma-display panels (PDPs).

Choon-Sang Park received his M.S. and Ph.D. degrees in electronic and electrical engineering from Kyungpook National University, Daegu, Korea, in 2006 and 2010, respectively. Since 2010 he has been a Post-Doctoral Fellow at the School of Electrical Engineering and Computer Science, Kyungpook National University. His current research interests include micro-discharge physics, MgO thin film, driving waveforms of plasma-display panels (PDPs), and surface analysis for new material.

Heung-Sik Tae received his B.S., M.S., and Ph.D. degrees in electrical engineering from the Seoul National University, Korea, in 1986, 1988, and 1994, respectively. Since 1995, he has been a Professor at the School of Electrical Engineering and Computer Science, Kyungpook National University, Daegu, Korea. His research interests include the optical characterization and driving waveform of plasma-display panels (PDPs). He is a member of the Society for Information Display (SID) an has been serving as an Editor for the *IEEE Transactions on Electron Devices* section on display technology since 2005.

Bhum Jae Shin received his B.S. degree from the Department of Electrical Engineering and his M.S. and Ph.D. degrees in plasma engineering from Seoul National University in 1990, 1992, and 1997, respectively. He worked on the development of PDPs as a Senior Researcher in the PDP team of Samsung SDI, Korea from 1997 to 2000. He worked on the capillary discharges as a Visiting Researcher in the Physics Department of the Stevens Institute of Technology, Hoboken, New Jersey, USA from 2000 to 2001. In 2003, he joined the Department of Electronics Engineering, Sejong University, Seoul, Korea, where he is now an assistant professor. His research interests include high-efficency cell structures and driving circuits of plasma-display panels (PDPs).

Jae Hyun Seo received his B.S. degree from the Department of Electrical Engineering and his M.S. and Ph.D. degrees in plasma engineering from Seoul National University in 1993, 1995, and 2000, respectively. He was with Plasma Display Panel (PDP) Division of Samsung SDI, Cheonan, Korea, from 2000 to 2002, where his work focused on the design of driving pulses in ACPDP. Since September 1, 2002, he has been a Professor in the Department of Electronics Engineering, University of Incheon, Incheon Korea. His research is currently focused on the high-efficiency PDP cell structure, driving method, and numerical modeling in PDPs. He is a member of the Society for Information Display (SID) and the Koeran Information Display Society.

Eun-Young Jung received her B.S. degree in physics from Daegu Catholic University, Kyungpook, Korea, in 1998 and her M.S. and Ph.D. degrees from Kyungpook National University, Daegu, Korea in physics in 2000 and 2006, respectively. She was Assistant Manager in the PDP Division, Orion PDP Company Ltd., Kyungpook, Korea from 2000 to 2003. She was also Assistant Manager in the PDP Division, Samsung SDI Company, Ltd., Cheonan City, Korea from 2003 to 2009. She is currently Senior Manager in the Core Technology Lab., Corporate R&D Center, Samsung SDI Company, Ltd., Cheonan City, Korea since 2009. Her current research interests include MgO thin film, simulation analysis, micro-discharge physics for plasma-display panels (PDPs), and surface analysis for new material.