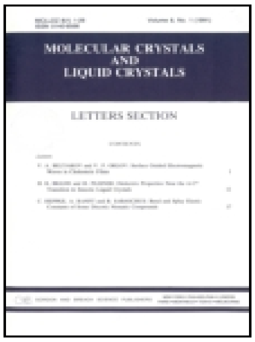


Molecular Crystals and Liquid Crystals

ISSN: 1542-1406 (Print) 1563-5287 (Online) Journal homepage: https://www.tandfonline.com/loi/gmcl20

Reduction of Permanent Image Sticking in AC Plasma Display Panel Using Negative Sustain Waveform

Choon-Sang Park , Sang-Yup Kim , Jae Hyung Kim & Heung-Sik Tae

To cite this article: Choon-Sang Park , Sang-Yup Kim , Jae Hyung Kim & Heung-Sik Tae (2011) Reduction of Permanent Image Sticking in AC Plasma Display Panel Using Negative Sustain Waveform, Molecular Crystals and Liquid Crystals, 551:1, 104-115, DOI: 10.1080/15421406.2011.600162

To link to this article: https://doi.org/10.1080/15421406.2011.600162

Published online: 18 Oct 2011.

Mol. Cryst. Liq. Cryst., Vol. 551: pp. 104–115, 2011

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2011.600162

Reduction of Permanent Image Sticking in AC Plasma Display Panel Using Negative Sustain Waveform

CHOON-SANG PARK,[1] SANG-YUP KIM,[2] JAE HYUN KIM,[1] AND HEUNG-SIK TAE[1,*]

[1]School of Electronics Engineering, College of IT Engineering, Kyungpook National University, Daegu 702-701, Korea
[2]PDP Module 1 Group, PDP Research Department 2, LG Electronics, Inc., Gumi 730-030, Korea

The permanent image sticking phenomena were examined and compared for the two different sustain driving waveforms such as the positive and negative sustain waveforms. To compare the permanent image sticking phenomena for both waveforms, the differences in the display luminance, chromaticity coordinate, color temperature, infrared emission, and discharge current were measured in the image sticking and non-image sticking cells. It was observed that the negative sustain waveform contributed to mitigating the permanent image sticking in comparison with the positive sustain waveform. This phenomenon appears due to the lesser degradation of the visible-conversion characteristics of the phosphor layer caused by the deposition of lower amounts of sputtered Mg species on the phosphor layers, as confirmed by V_t closed curve, atomic force microscope, and photoluminescence analyses.

Keywords AC-PDP; negative sustain waveform; permanent image sticking; luminance; current; CIE (1931) chromaticity coordinate; color temperature; firing voltage; V_t closed curve; MgO layer; atomic force microscope; photoluminescence

1. Introduction

The image sticking problems of current plasma display panels (PDPs) still need to be improved in order to realize a high-quality in IPTV (Internet Protocol Television), PID (Public Information Display), and electronic copyboards. Image retention means a temporal image sticking that is easily recoverable through a minor treatment [1]–[5], whereas image sticking means a permanent image sticking that is not recoverable in spite of severe treatment [6]–[10].

The decrease in the visible conversion caused by the deposition of Mg species on the phosphor layer causes a permanent image sticking, which would be intensified in the case of the direct ion bombardment onto the phosphor layer during the sustain discharge [8]–[10]. Thus, it is expected that the suppression of the ion bombardment into the phosphor layer during the sustain discharge would reduce the permanent image sticking.

*Corresponding autnor. E-mail: hstae@ee.knu.ac.kr

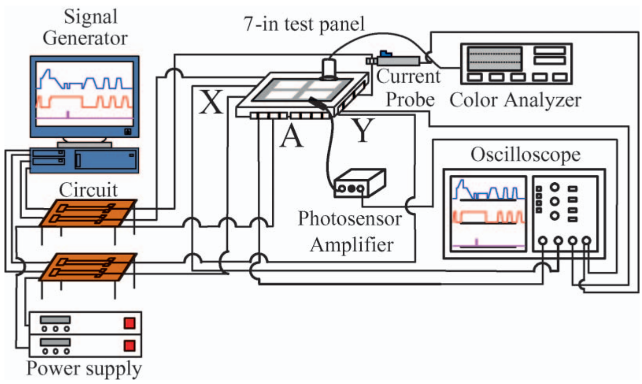


Figure 1. Schematic diagram of optical and electrical measurement systems used to measure luminance, IR emission, and discharge current.

In the previous related research, the negative driving waveform contributed to improving the reset and sustains discharge characteristics [11]–[14]. However, the researches of the negative sustain driving waveform for image stickings have not been reported yet. Accordingly, to reduce the ion bombardment on the phosphor layers during the sustain discharge, this paper investigates the effects of the negative sustain waveform on the permanent image sticking in ac-PDP.

2. Experimental Setup

Figure 1 shows a schematic diagram of the optical and electrical measurement system used in this study. A color analyzer (CA-100), photosensor amplifier (Hamamatsu C6386), signal generator, and current probe (AP015) were used to measure the luminance, CIE (1931) chromaticity coordinate, color temperature, IR emission, discharge current, and V_t closed curve of the test panel with the two different sustain waveforms, respectively. The gas chemistry and pressure in the 7-inch test panel were Ne-Xe (4%) and 400 Torr. The detailed specifications for the 7-inch test panel are listed in Table 1.

Figure 2 (a) shows the three electrodes, X, Y, and A, in the 7-inch test panel used to monitor the permanent image sticking, where the square-shaped patterns (positive sustain (Ref.) and negative sustain (New)) are the discharge regions and another regions are the non-discharge regions. Figures 2 (b) and (c) show the sustain driving waveforms employed

Table 1. Specifications of 7-inch test panel employed in this research

Front Panel		Rear Panel	
ITO width	310 μm	Barrier rib width	80 μm
ITO gap	60 μm	Barrier rib height	125 μm
Bus width	100 μm	Address width	100 μm
Cell pitch		360 μm $\times$ 1080 μm	
Gas chemistry		Ne-Xe (4%)	
Gas pressure		400 Torr	
Barrier rib type		Stripe-type rib	

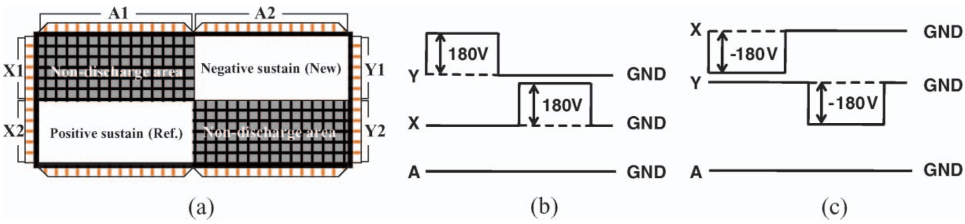


Figure 2. (a) Three electrodes X, Y, and A in 7-inch test panel and (b) positive (Ref.) and (c) negative (New) sustain waveforms used to monitor permanent image sticking.

in this study, where (b) is the positive and (c) is the negative sustain waveform during a sustain period. The voltage levels were fixed at 180 V for the positive sustain pulse and -180 V for the negative sustain pulse. The frequency for the sustain period was 50 kHz. The duty ratio of the sustain pulses was 40% and the total display time was 850 hours.

3. Results and Discussion

3.1 Image Sticking with Applying Positive and Negative Sustain Waveforms

(1) Monitoring of Luminance, Chromaticity Coordinate, and Color Temperature. Figure 3 shows the changes in the luminance and the normalized luminance in the discharge region measured during the sustain discharge up to 850 hours on the 7-inch test panel when applying the positive and negative sustain waveforms. As shown in Figure 3 (b), the normalized luminance was defined as the ratio of the luminance difference between the initial luminance and the luminance with a specific displaying time in the discharge region. Thus, the normalized luminance of 1 corresponds to no luminance difference between the before and after sustain discharges, implying no image sticking [10]. As shown in Figures 3 (a) and (b), when applying the negative sustain waveform, the luminance and normalized luminance were observed to be higher than that in the positive sustain waveform, indicating that the negative sustain waveform contributed to reducing the permanent image sticking.

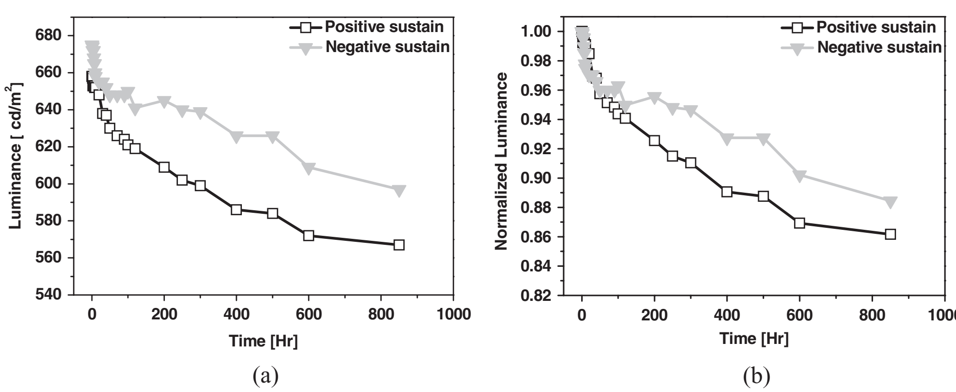
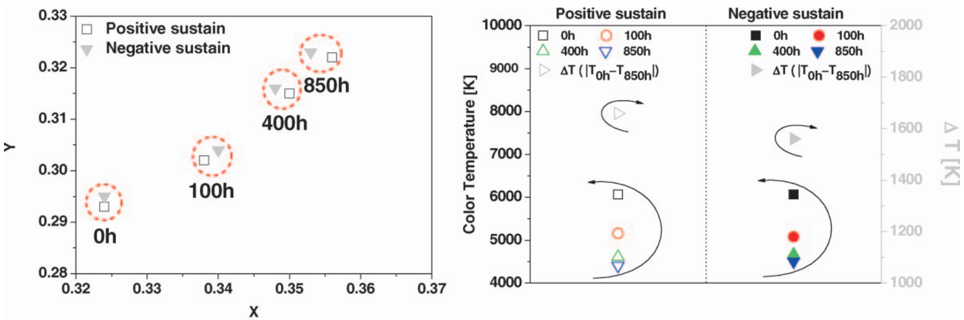


Figure 3. Comparison of (a) luminance and (b) normalized luminance relative to display time of square-type image when applying positive and negative sustain waveforms.



(a) (b)

Figure 4. Comparison of (a) CIE (1931) chromaticity coordinates and (b) color temperatures relative to display time when applying positive and negative sustain waveforms.

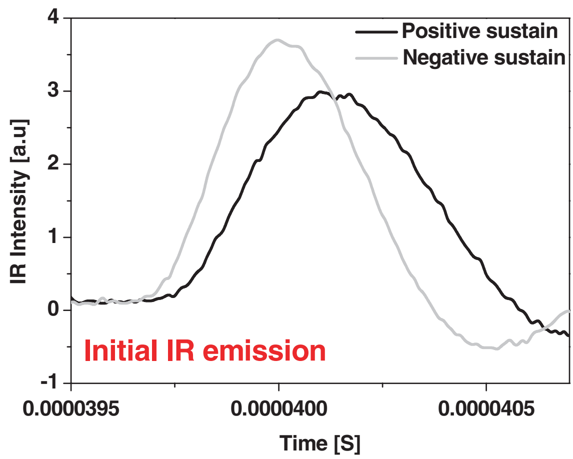


Figure 5. Comparison of IR emission waveforms during initial sustain discharge when applying positive and negative sustain waveforms.

Figure 4 shows the changes in the International Commission on Illumination CIE (1931) chromaticity coordinates and related color temperatures in the discharge region measured during the sustain discharge up to 850 hours on the test panel when applying the positive and negative sustain waveforms. As shown in Figures 4 (a) and (b), the chromaticity coordinates x and y were changed during the 850 hour-sustain discharge with concurrent deterioration of color temperature. However in the case of applying the negative sustain waveform, the difference in the color temperature was decreased in comparison with the positive sustain waveform.

(2) Monitoring of IR Emission. Figure 5 shows the infrared (IR: 828 nm) emission during the initial sustain discharge on the test panel by applying the positive and negative sustain waveforms. As shown in Figure 5, when applying the negative sustain waveform, the initiation point of IR emission was shifted to the left, and IR emission peak was also higher, implying that the sustain discharge was produced faster and stronger in the case of applying the negative sustain waveform. Our previous results indicated that direct application of negative sustain waveform to the sustain electrode accumulating electrons caused a rapid acceleration of the electrons, thereby inducing a fast and intense discharge within the cell [11].

Figures 6 and 7 show the changes in the IR emissions in the discharge region measured before and after the 850 hour-sustain discharge when applying the positive (Figure 6) and negative (Figure 7) sustain waveforms. As shown in Figure 6, when applying the positive sustain waveform, the IR peak after sustain discharge was shifted to the left and intensified compared to that before sustain discharge. However, as shown in Figure 7, when applying the negative sustain waveform, the IR emissions in the discharge region were almost the same before and after a discharge in spite of very intense discharge as Figure 5.

Figure 8 shows the changes in the normalized integrated values of the IR emission in the discharge region measured during the sustain discharge up to 850 hours on the test panel while applying the positive and negative sustain waveforms. As shown in Figure 8, when applying the negative sustain waveform, the normalized integrated values of the IR emission was observed to be higher than that in the positive sustain waveform. This result

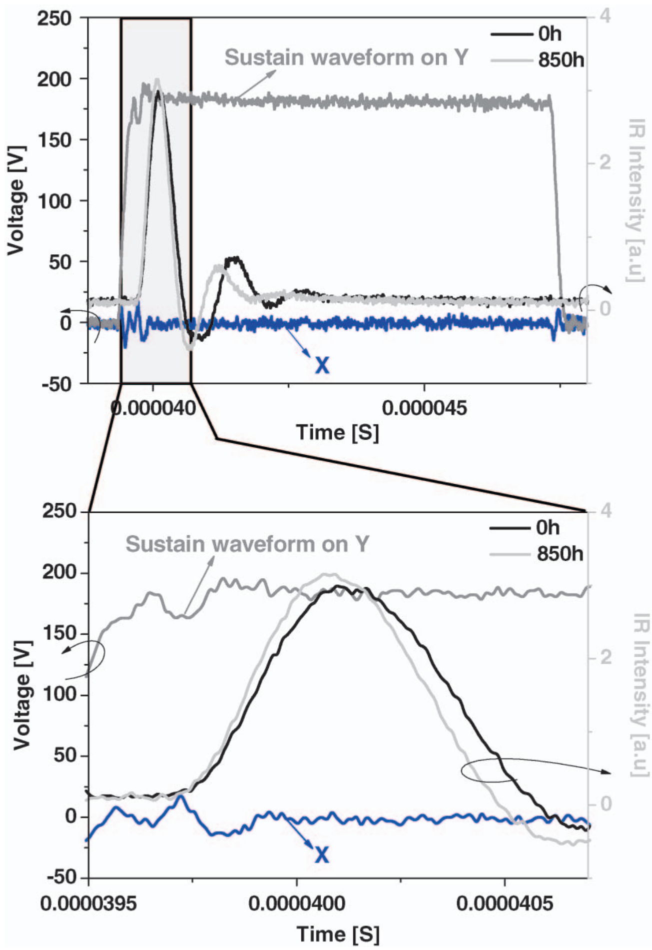


Figure 6. Comparison of IR emission waveforms during sustain discharge measured from discharge region before and after 850 hour-sustain discharge when applying positive sustain waveform.

also indicates that the negative sustain waveform contributes to reducing the permanent image sticking.

(3) Monitoring of Discharge Current. Figure 9 shows a comparison of the sustain discharge currents during the initial sustain discharge on the test panel when applying the positive and negative sustain waveforms. As shown in Figure 9, when applying the negative sustain waveform, the initiation point of sustain discharge current was shifted to the left, and sustain discharge current was also higher, implying that the sustain discharge was produced faster and stronger in the case of applying the negative sustain waveform, which was also confirmed by the IR emission in Figure 5 [11].

Figure 10 shows the changes in the sustain discharge currents in the discharge region measured before and after the 850 hour-sustain discharge when applying the (a) positive and (b) negative sustain waveforms. As shown in Figure 10 (a), when applying the positive sustain waveform, the peak of the sustain discharge current after sustain discharge was intensified compared to that before sustain discharge. However, as shown in Figure 10

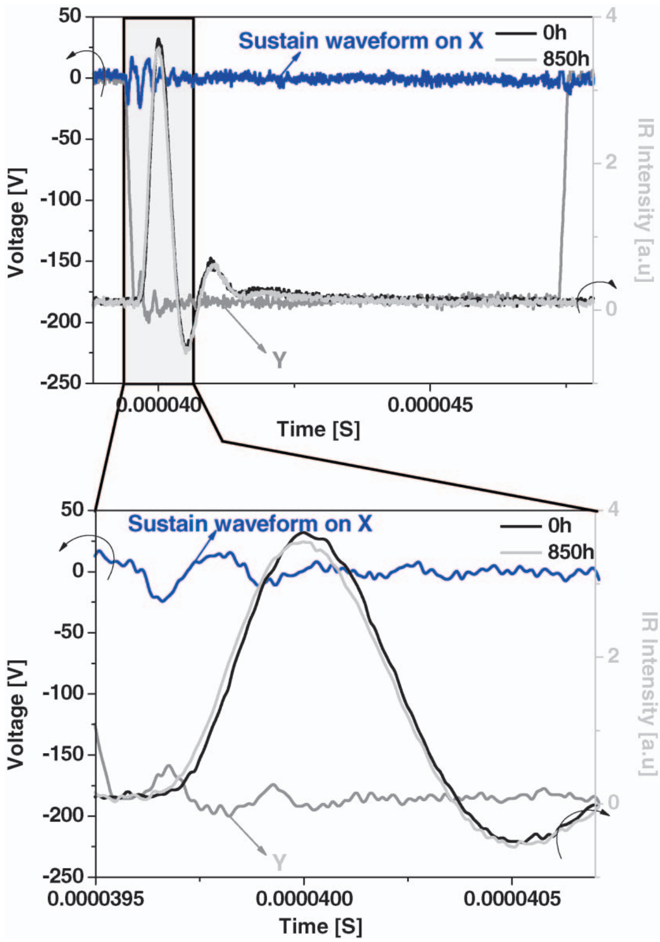


Figure 7. Comparison of IR emission waveforms during sustain discharge measured from discharge region before and after 850 hour-sustain discharge when applying negative sustain waveform.

(b), when applying the negative sustain waveform, the sustain discharge currents in the discharge region were almost the same before and after a discharge in spite of the increase in the sustain discharge current in Figure 9.

(4) Monitoring of Firing Voltage Using V_t Closed Curve. To investigate the reason for the enhanced permanent image sticking in the case of the negative sustain waveform, as shown in Figure 11, the V_t closed curves were measured for both the discharge and non-discharge regions when applying the positive and negative sustain waveforms without any initial wall charges [7]–[10]. Table 4 shows the detailed changes in the firing voltages obtained from the V_t closed curves measured for the discharge and non-discharge regions in Figure 11. As shown in Figure 11 and Table 2, for the discharge region when applying the negative sustain waveform, where an iterant strong sustain discharge was produced for 850 hour, the firing voltages of the discharge regions for sides I (X-Y), II (A-Y), III (A-X), and IV (Y-X) under MgO-cathode conditions were slightly increased in comparison with the positive sustain waveform. This result meant that the MgO layer when applying the negative

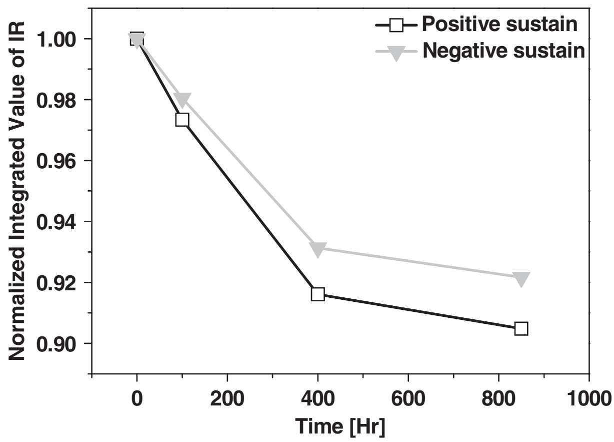


Figure 8. Comparison of normalized integrated values of IR emission waveforms relative to display time when applying positive and negative sustain waveforms.

sustain waveform was more damaged or sputtered than that of the positive sustain waveform. However, as shown in Figure 11 and Table 2, when applying the negative sustain waveform, the firing voltages of the discharge regions for sides V (Y-A) and VI (X-A) under phosphor-cathode conditions were increased in comparison with the positive sustain waveform. For the negative sustain waveform, the reduction in the difference of firing voltage between the discharge and non-discharge regions under the phosphor cathode condition was mainly due to the less deposit of Mg species with a higher secondary electron emission coefficient on the phosphor layer in spite of the increase in the sputtered Mg species from the MgO surface.

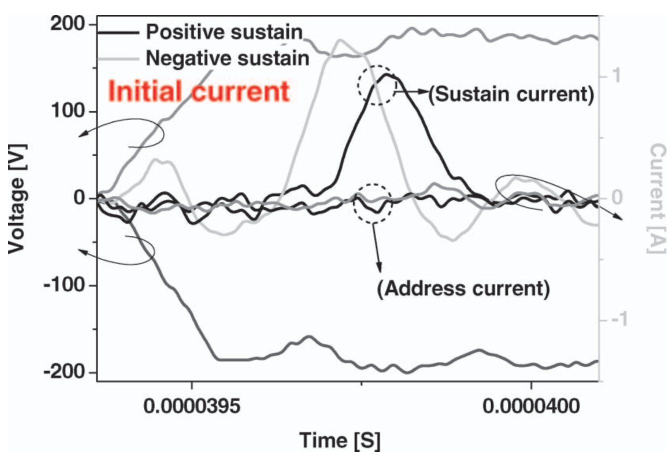


Figure 9. Comparison of discharge current waveforms during initial sustain discharge when applying positive and negative sustain waveforms.

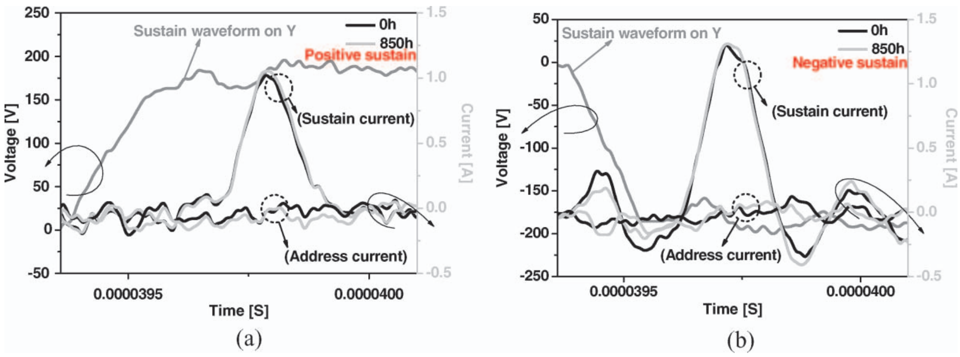


Figure 10. Comparison of discharge current waveforms during sustain discharge measured from discharge region before and after 850 hour-sustain discharge when applying (a) positive and (b) negative sustain waveforms.

3.2 Analysis of Image Sticking Induced by Negative Sustain Waveform

To identify the Mg species deposited on the phosphor layer and observe the surface morphology of MgO layer, two kinds of the measurements were carried out in this experiment as follows; AFM (Atomic Force Microscope) for surface characteristics and PL (Photoluminescence) for analyzing the photo intensity emitted from the phosphor layers.

(1) Monitoring of MgO Surface. Figure 12 shows the changes in the two- and three-dimensional AFM images of MgO surface for the discharge and non-discharge regions after the 850 hour-sustain discharge when applying the positive and negative sustain waveforms. The roughness and morphology of the MgO surfaces in discharge regions were greater than those in the non-discharge region. This increased roughness and morphology for the discharge region were mainly due to the ion bombardment during the sustain discharge. As shown in Figure 12, for the discharge region by the negative sustain waveform, the

Table 2. Firing voltages measured for discharge and non-discharge regions when applying positive and negative sustain waveforms from test panel

	Firing voltage		
		Discharge region	
Region	Non-discharge region	Positive sustain	Negative sustain
MgO Cathode			
I	232 V	221 V	224 V
II	155 V	160 V	161 V
III	164 V	169 V	170 V
IV	228 V	227 V	235 V
Phosphor Cathode			
V	241 V	174 V	183 V
VI	250 V	171 V	182 V

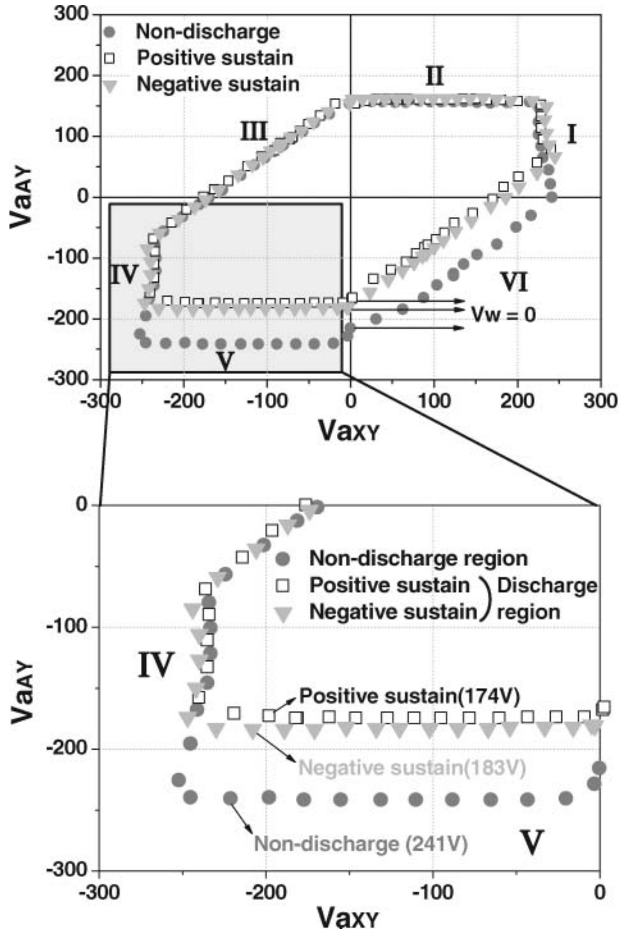


Figure 11. Comparison of V_t closed curves for discharge and for non-discharge regions after 850 hour-sustain discharge without initial wall charges when applying positive and negative sustain waveforms, where side I means threshold breakdown voltage (V_{tXY}) between X-Y electrodes, side II means threshold breakdown voltage (V_{tAY}) between A-Y electrodes, side III means threshold breakdown voltage (V_{tAX}) between A-X electrodes, side IV means threshold breakdown voltage (V_{tYX}) between Y-X electrodes, side V means threshold breakdown voltage (V_{tYA}) between Y-A electrodes, and side VI means threshold breakdown voltage (V_{tXA}) between X-A electrodes.

MgO surface was more damaged or sputtered than that of the positive sustain waveform, implying that the Mg species were more sputtered from MgO layer due to the intense discharge produced by the negative sustain waveform, as shown in Figures 5 and 9.

(2) Monitoring of Photoluminescence from Phosphor Layers. Figure 13 shows the changes in the profiles of photo intensity (visible rays, 380∼740 nm) emitted from the phosphor layers when the vacuum ultra violet (VUV, 146 nm using Kr lamp) irradiated the surface of the phosphor layers in the discharge and non-discharge regions after the 850 hour-sustain discharge when applying the positive and negative sustain waveforms using a PL analysis. As shown in Figure 13, when applying the negative sustain waveform, the difference

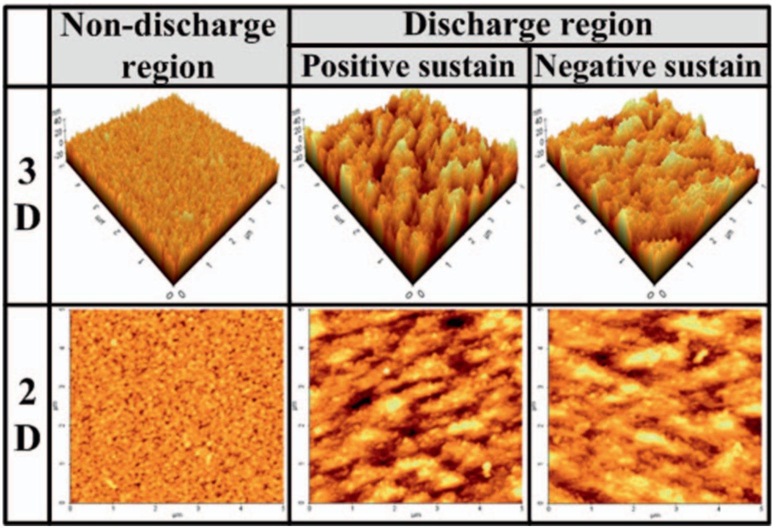


Figure 12. Comparison of two (2)- and three (3)-dimensional AFM images of MgO surface changes in discharge and non-discharge regions after 850 hour-sustain discharge when applying positive and negative sustain waveforms.

of the PL intensity emitted from the phosphor layers between the discharge and non-discharge regions was reduced in comparison with the positive sustain waveform. The better permanent image sticking characteristics for the negative sustain waveform were mainly due to the less degradation of visible conversion capability from VUV by the phosphor layer as a result of the decreased deposition of Mg species onto the phosphor layers in spite of the increase in the sputtered Mg species from the MgO surface. When applying the negative sustain waveform, the less deposit of Mg species on the phosphor layer was

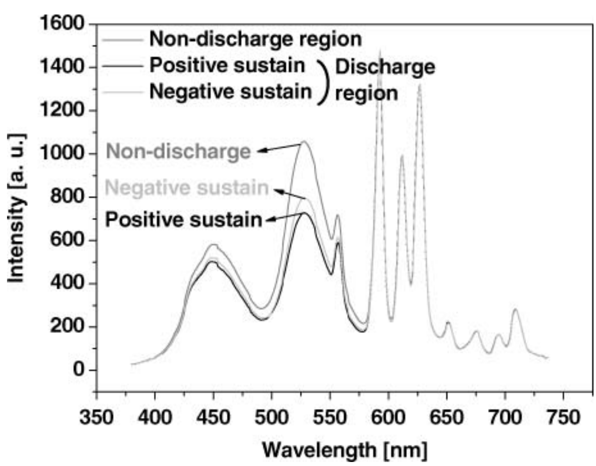


Figure 13. Comparison of profiles of photo intensity (146 nm using Kr lamp) changes detected from phosphor layers in discharge and non-discharge regions after 850 hour-sustain discharge when applying positive and negative sustain waveforms using PL analysis.

presumably due to more decrease in the re-crystallization of Mg species with the phosphor layer by suppressing the ion bombardment onto the phosphor in the case of adopting the negative sustain waveform [10]. Therefore, it is expected that these experimental results will help to solve the permanent image sticking problem or to enhance the life-time of the phosphor layer in the current PDP-TVs.

Conclusion

The effects of the types of sustain waveform such as the positive and negative sustain waveforms on the permanent image sticking were investigated. Our experiment showed that the negative sustain waveform was able to improve the permanent image sticking by mitigating the deposition of Mg species onto the phosphor layer. Thus, it is expected that the negative sustain waveform will help to reduce the permanent image sticking in ac PDP-TV.

Acknowledgments

This work was supported in part by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0014341) and in part by Brain Korea 21 (BK21).

References

[1] Kim, J. H., Park, C.-S., Kim, B.-S., Park, K.-H., & Tae, H.-S. (2007). *JID'07*, **8**(3), 29–33.
[2] Park, C.-S., Cho, B.-G., & Tae, H.-S. (2008). *JID'08*, **9**(4), 39–44.
[3] Park, C.-S., Kim, S. H., Kim, J. H., & Tae, H.-S. (2009). *JID'09*, **10**(4), 195–201.
[4] Tae, H.-S., Park, C.-S., Cho, B.-G., Han, J.-W., Shin, B. J., Chien, S.-I., & Lee, D, H. (2006). *IEEE Trans. Plasma Science*, **34**(3), 996–1003.
[5] Park, C.-S. & Tae, H.-S. (2009). *IEICE Trans. Electronics*, **E92-C**(1), 161–165.
[6] Nikishin, N., Manakhov, A., Kim, Y.-K., Hur, M., & Heo, E.-G. (2008). *IMID'08*, **8**, 381–383.
[7] Park, C.-S., Tae, H.-S., Kwon, Y.-K., & Heo, E.-G. (2009). *Mol. Cryst. Liq. Cryst.*, **499**, 213–223.
[8] Park, C.-S., Tae. H.-S., Kwon, Y.-K., & Heo, E. G. (2007). *IEEE Trans. Electron Devices*, **54**(6), 1315–1320.
[9] Park, C.-S., Jang, S.-K., Tae, H.-S., Jung, E.-Y., & Ahn, J.-C. (2009). *J. Soc. Inf. Disp.*, **17**(11), 977–985.
[10] Park, C.-S., Kim, J. H., Jang, S.-K., Tae, H.-S., & Jung, E.-Y. (2010). *J. Soc. Inf. Disp.*, **18**(8), 606–613.
[11] Lim, J. K. & Tae, H.-S. (2008). *IEEE Trans. Electron Devices*, **55**(10), 2595–2601.
[12] Kang, J. W. (2009). *IMID'09*, **9**, 97–100.
[13] Park, W. H., Lee, S. J., Lee, J. Y., & Kang, J. (2009). *IMID'09*, **9**, 728–731.
[14] Eom, S. H., Kang, J. W., Park, H. I., & Mun, S. H. (2007). *IDW'07*, **14**, 843–846.