

Effects of Positive-Biased Conditions of Address Electrode During Sustain Discharge on Permanent Image Sticking in AC Plasma Display Panel

Choon-Sang Park and Heung-Sik Tae, *Senior Member, IEEE*

Abstract—The permanent image sticking phenomena were examined and compared for the two bias conditions of the address electrode during sustain discharge such as the grounded and positive-biased (or floated) address electrodes. To compare the permanent image sticking phenomena for both bias conditions, the differences in the display luminance, chromaticity coordinate, color temperature, infrared emission, and discharge current of the image sticking cells and the nonimage sticking cells were measured. It was observed that the positive-biased or floated address electrodes contributed to mitigating the permanent image sticking in comparison with the grounded address electrode during sustain discharge. 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.

Index Terms—AC-plasma display panel, address biased, atomic force microscope, CIE (1931) chromaticity coordinate, color temperature, floated, ion bombardment, luminance, permanent image sticking, photoluminescence, V_t closed curve.

I. 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. The permanent image sticking induced by ion bombardment during a long-duration plasma discharge affects the life time of PDPs and needs to be improved. In the discharge region or permanent image sticking region where a strong sustain discharge is repeatedly produced, Mg particles are sputtered from the MgO surface due to the severe bombardment of ions onto the MgO protecting layer, and these sputtered Mg particles are then predominantly deposited on the phosphor layer [1]–[13]. The resultant degradation of the phosphor layer due to the sputtered Mg particles is thus the major

cause of permanent image sticking in current PDPs [7, 11]. However, experiments by the current authors have shown that Mg particles sputtered from the MgO surface do not always induce degradation of the phosphor layer, implying that phosphor degradation occurs only when the sputtered Mg particles are crystallized on the phosphor layer [7, 11]. Furthermore, the same experiments also confirmed that the crystallization of the sputtered Mg particles on the phosphor layer strongly depended on the deposition of charged Mg particles on the phosphor layer. In the previous related research [11], the secondary ion mass spectroscopy (SIMS) confirmed that ion bombardment of the phosphor layer facilitated the crystallization of the Mg particles sputtered from the MgO surface during a discharge, thereby degrading the visible conversion of the phosphor layer and eventually lowering the luminance and color temperature [11].

Accordingly, in order to reduce the ion bombardment on the phosphor layers during the sustain discharge, this paper investigates in more detail the effects of the positive-biased address electrode on the permanent image sticking in ac-PDP.

II. EXPERIMENTAL SETUP

Fig. 1 shows a schematic diagram of the optical and electrical measurement system used in this study, where X is the sustain electrode, Y is the scan electrode, and A is the address electrode. 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, respectively. A 7-in. panel with a working gas pressure of 400 Torr was employed in this study, and its structure and dimensions were an XGA grade PDP with a box-type barrier rib. The gas mixtures used were Ne-Xe (11%). The detailed panel specifications are listed in Table I. The MgO thin film was deposited on the dielectric layer of the ac-PDP by using ion-plating evaporation, and the oxygen and hydrogen flow rates were kept at 220 and 60 sccm, respectively, during the deposition. For the front glass plate, the MgO surface, which was deposited as a protective layer on the sustain and scan electrodes, was exposed to the discharge space, whereas for the rear glass plate, the phosphor layer on the address electrode was exposed to the discharge space. The surface discharge was produced by applying 180 V to one of the sustain or scan electrode, which resulted in heavy ion bombardment of the MgO surface [12]. However, a part of

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The authors are with the School of Electronics Engineering, College of IT Engineering, Kyungpook National University, Daegu 702-701, Korea (e-mail: purplepcs@ee.knu.ac.kr; hstae@ee.knu.ac.kr).

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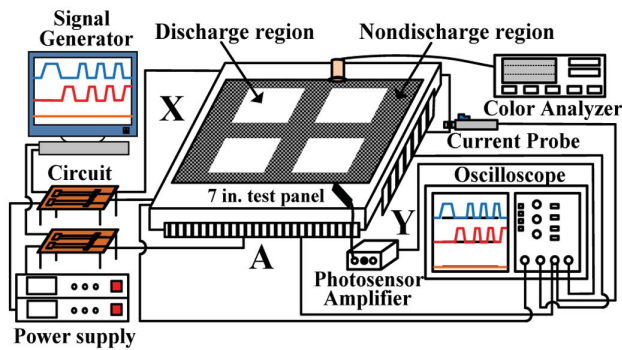


Fig. 1. Schematic diagram of optical and electrical measurement systems used to measure luminance, IR emission, and discharge current.

TABLE I
SPECIFICATIONS OF 7-IN AC-PDP USED IN THIS PAPER

Front panel		Rear panel	
ITO width	230 μm	Barrier rib width	65 μm
ITO gap	80 μm	Barrier rib height	120 μm
Bus width	60 μm	Address width	95 μm
Pixel Pitch	912 μm \times 693 μm		
Gas chemistry	Ne-Xe (11%)		
Barrier rib type	Closed rib		

the ions in the plasma discharge bombarded the phosphor layer on the address electrode. Thus, varying the potentials of the address electrode during the surface discharge can affect the ion bombardment conditions for both the MgO surface and phosphor layer. Fig. 2 shows the sustain driving waveforms with three different bias conditions of the address electrode employed in this study, where (a) is the grounded ($= 0$ V) address electrode (this is 'reference case'), (b) and (c) are the positive-biased ($= 60$ V) and (floated) address electrodes, respectively. The sustain voltage level was fixed at 180 V. The frequency for the sustain period was 50 kHz. The duty ratio of the sustain pulses was 40% and the total sustain discharge time was 850 hours.

III. PERMANENT IMAGE STICKING PHENOMENA WITH GROUNDED AND POSITIVE-BIASED ADDRESS ELECTRODES DURING SUSTAIN DISCHARGE

A. Monitoring of Luminance, Chromaticity Coordinate, and Color Temperature

Fig. 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 under variously biased address electrodes, such as grounded and positive-biased or floated address electrodes. As shown in Fig. 3(b), the normalized luminance was defined as the ratio of the luminance difference between the initial luminance and the luminance with a specific sustain discharge 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 [13]. In cases of the positive-biased or floated address electrodes, the initial luminance was slightly increased at the same sustain

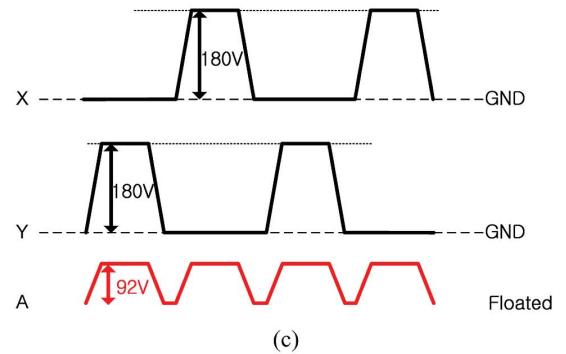
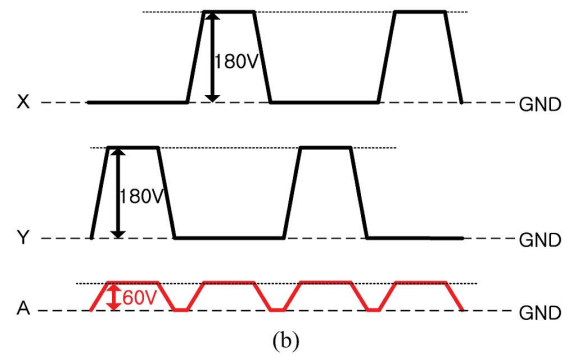
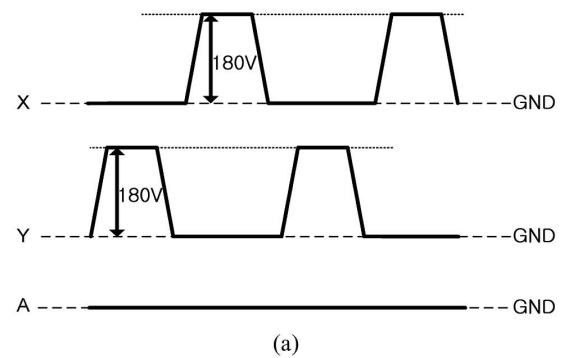


Fig. 2. Schematic diagrams of sustain driving waveform applied to three electrodes. (a) Grounded ($=0$ V) address electrode (reference case) and positive-biased. (b) ($=60$ V). (c) (Floated) address electrodes.

voltage level. Nonetheless, as shown in Figs. 3(a) and (b), for positive-biased or floated address electrodes, the luminance and normalized luminance were observed to be higher than that in the positive sustain waveform, indicating that the positive-biased or floated address electrodes contributed to reducing the permanent image sticking.

Fig. 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 under variously biased address electrodes, such as grounded and positive-biased or floated address electrodes. As shown in Figs. 4(a) and (b), the chromaticity coordinates x and y , and the color temperature were changed during the 850 hour-sustain discharge. However, for positive-biased or floated address electrodes, the variation degree in the color temperature was reduced in comparison with the grounded address electrode.

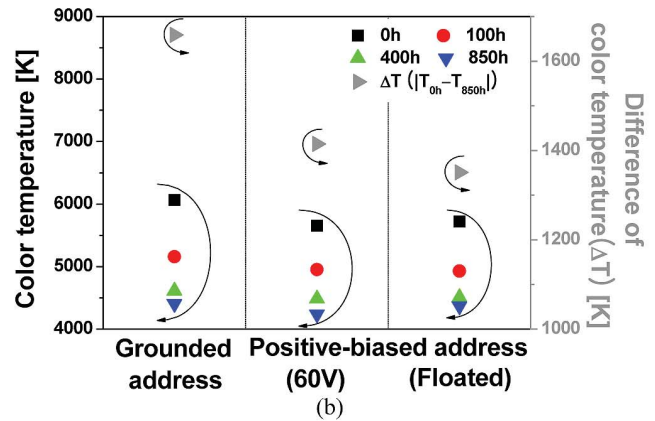
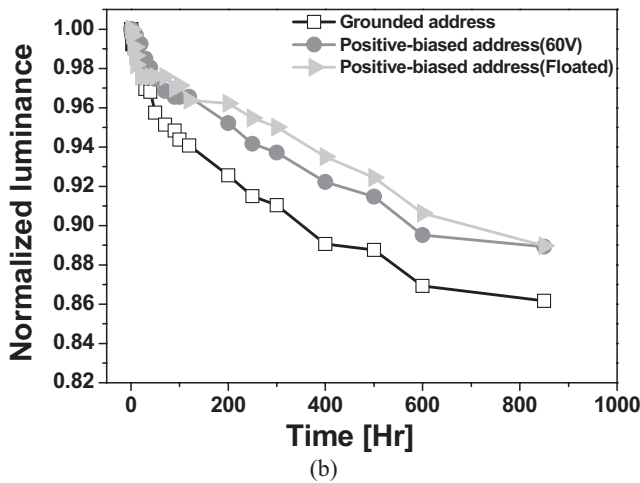
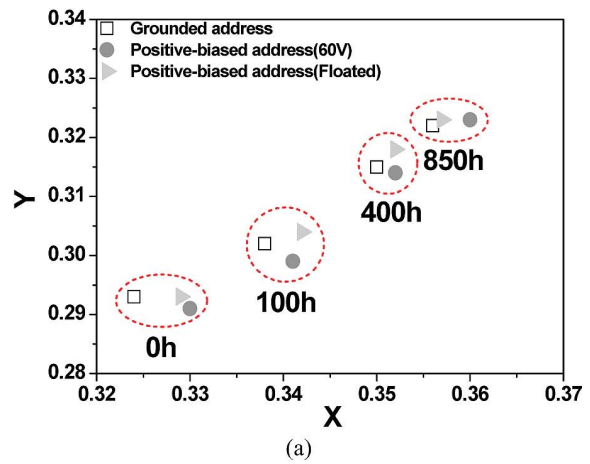
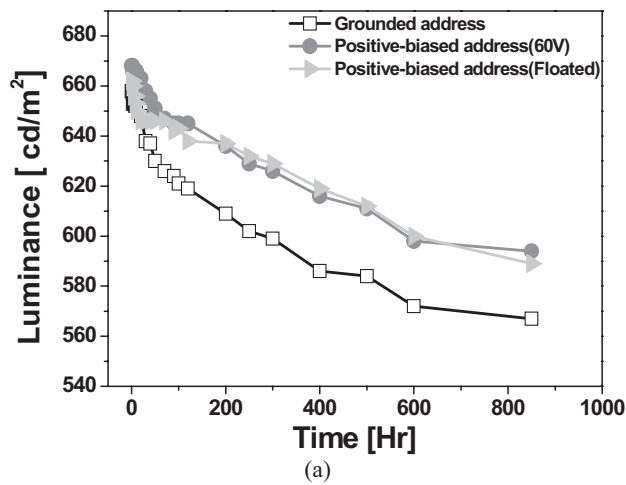


Fig. 3. Comparison of (a) luminance and (b) normalized luminance relative to sustain discharge time under three different bias conditions, such as grounded and positive-biased (60 V or floated) address electrodes during sustain discharge.

Fig. 4. Comparison of (a) CIE (1931) chromaticity coordinates and (b) color temperatures relative to sustain discharge time with grounded and positive-biased (60 V or floated) address electrodes during sustain discharge.

B. Monitoring of IR Emission

Fig. 5 shows the infrared (IR: 828 nm) emissions during the initial sustain discharge on the test panel under variously biased address electrodes, such as grounded and positive-biased or floated address electrodes. As shown in Fig. 5, for positive-biased or floated address electrodes, the IR emission peaks were higher, implying that the sustain discharges were produced a little stronger in the cases of the positive-biased or floated address electrodes.

Fig. 6 shows the changes in the IR emissions in the discharge region measured before and after the 850 hour-sustain discharge under variously biased address electrodes, such as (a) grounded and (b) positive-biased or (c) floated address electrodes. The IR signals were measured using the Hamamatsu C6386 detector. The under and overshoot in the IR signals in Fig. 6 were mainly due to the high gain setting of the detector. As shown in Figs. 6(a) and (b), for grounded or positive-biased address electrodes, the IR peaks after the 850-hour sustain discharge were shifted to the left and intensified compared to that before sustain discharge. However, as shown in Fig. 6(c), for floated address electrode, the IR emissions

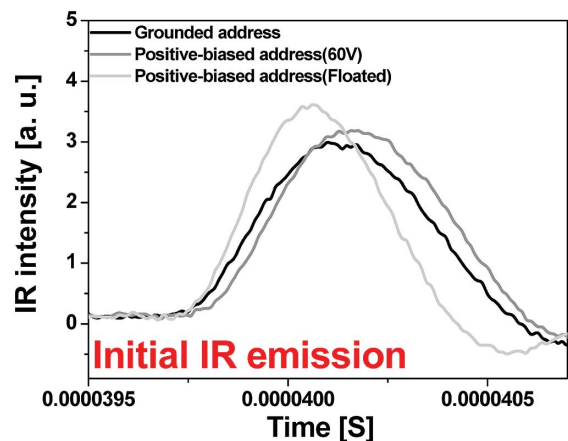


Fig. 5. Comparison of IR emission waveforms measure under three different bias conditions, such as grounded and positive-biased (60 V or floated) address electrodes during initial sustain discharge.

in the discharge region were observed to be almost the same before and after a discharge in spite of intense discharge as shown in Fig. 5.

Fig. 7 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 under three different sustain

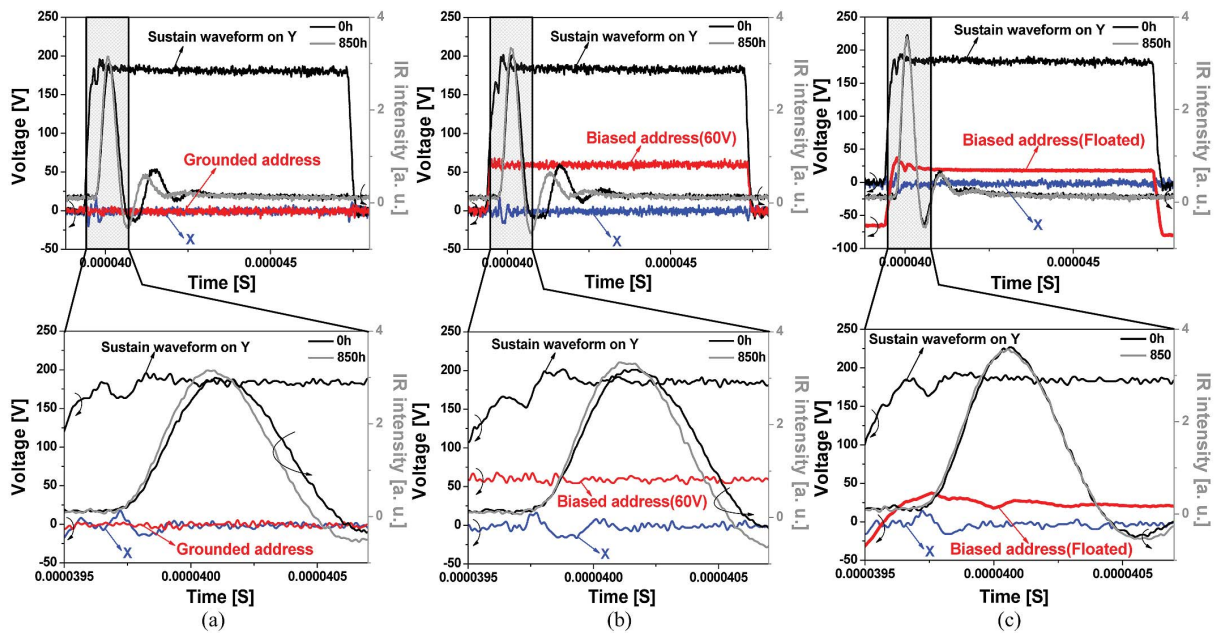


Fig. 6. Comparison of IR emission waveforms during sustain discharge measured from discharge region before and after 850 h-sustain discharge with (a) grounded and positive-biased, (b) 60 V or (c) (floated) address electrodes during sustain discharge.

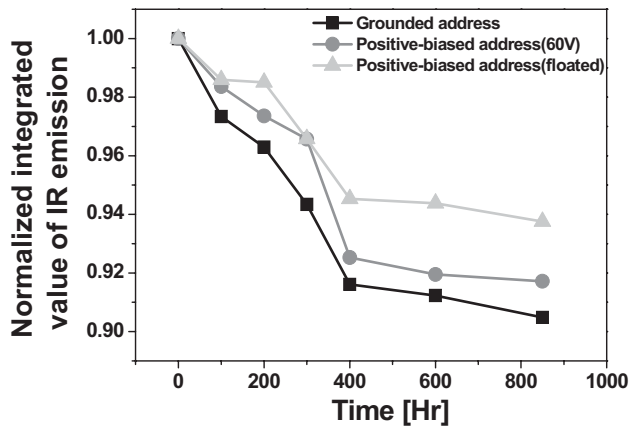


Fig. 7. Comparison of normalized integrated values of IR emission waveforms relative to display time with grounded and positive-biased (60 V or floated) address electrodes during sustain discharge.

pulsing conditions such as grounded and positive-biased or floated address electrodes. As shown in Fig. 7, for positive-biased or floated address electrodes, the normalized integrated values of the IR emission were observed to be higher than that in the grounded address electrode. This result also indicates that the specific sustain pulsing conditions such as positive-biased or floated address electrodes can mitigate the long-time luminance degradation, thereby contributing to reducing the permanent image sticking.

C. Monitoring of Discharge Current

Fig. 8 shows a comparison of the (a) sustain and (b) address discharge currents during the initial sustain discharge on the test panel under variously biased address electrodes, such as grounded and positive-biased or floated address electrodes.

As shown in Fig. 8(a), for positive-biased or floated address electrodes, the initiation points of sustain discharge current were shifted to the left, and the sustain discharge current peaks were also higher, implying that the sustain discharge was produced faster and stronger thanks to the positively applied bias of the address electrodes. In Fig. 8(b), the address current flowing to the address electrode has two polarities during the surface discharge. The negative polarity of the address current indicates the incidence of ions from the sustain discharge, whereas the positive polarity of the address current indicates the incidence of electrons from the sustain discharge. As shown in Fig. 8(b), for positive-biased address electrode, the address discharge current produced by ions was reduced compared to that for the grounded address electrode. The reduction in the address discharge current resulted from the decrease in the ion bombardment onto the phosphor layer during the sustain discharge.

D. Monitoring of Firing Voltage Using V_t Closed Curve

To investigate the reason for the enhanced permanent image sticking under the positive-biased or floated address electrode conditions, as shown in Fig. 9, the V_t closed curves were measured for both the nondischarge and discharge regions under variously biased conditions without any initial wall charges [14]. In Fig. 9, the plasma discharge has not been produced in the nondischarge region, whereas the plasma discharge has been produced continuously for 850 hours in the discharge region. In particular, the degradation degree of the phosphor layer in the discharge region can be estimated by comparing the firing voltage in (V) side of the V_t curve for both nondischarge and discharge regions. As shown in Fig. 9, in discharge region, the firing voltages under the MgO cathode condition, i.e., sides I (X-Y), II (A-Y), III (A-X), and

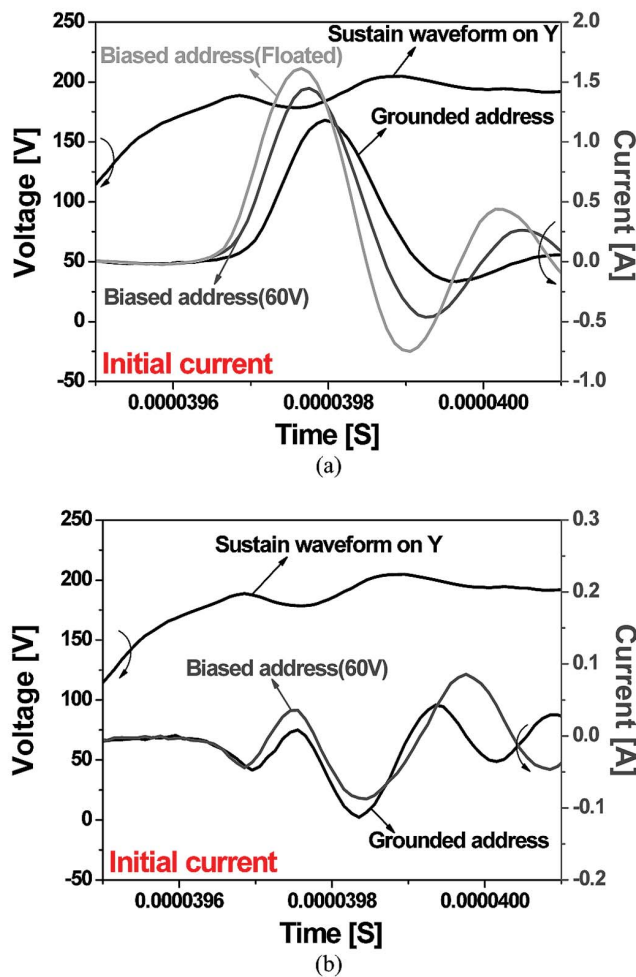


Fig. 8. Comparison of (a) discharge and (b) address current waveforms during initial sustain discharge with grounded and positive-biased (60 V or floated) address electrodes during sustain discharge.

IV (Y-X) were observed to be slightly higher for the positively biased address electrodes, meaning that the MgO surfaces were more damaged or sputtered. However, in (V) and (VI) sides under the phosphor cathode condition, the firing voltage for the grounded address electrode showed the lowest value, meaning that the Mg species were more deposited on the phosphor layer in case of the grounded address electrode. In other words, for the positive-biased or floated address electrodes, the reduction in the difference of firing voltage between the discharge and nondischarge 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.

IV. ANALYSIS ON REDUCTION OF PERMANENT IMAGE STICKING INDUCED BY POSITIVE-BIASED OR FLOATED ADDRESS ELECTRODES DURING SUSTAIN DISCHARGE

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)

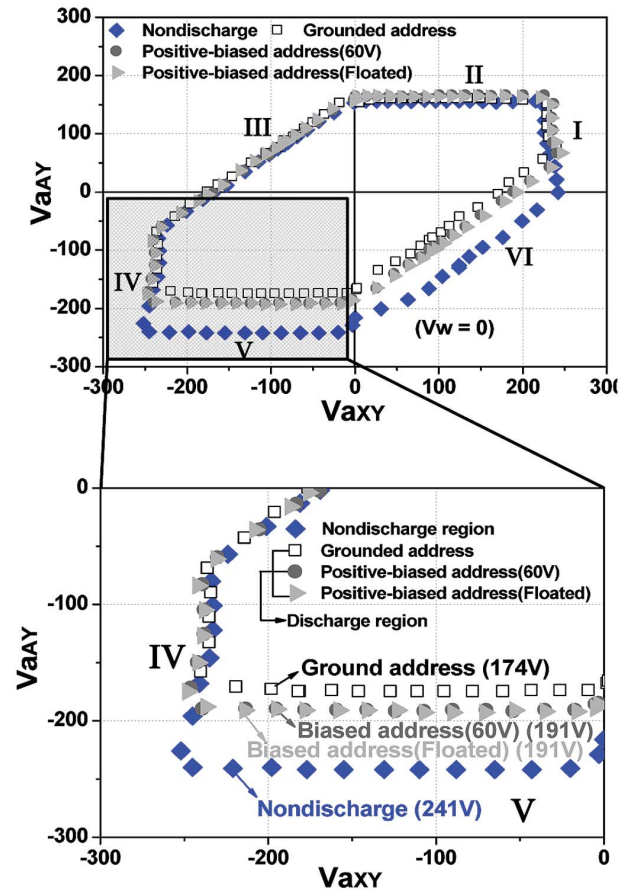


Fig. 9. Comparison of V_t closed curves for nondischarge and discharge regions after 850 h-sustain discharge without initial wall charges with grounded and positive-biased (60 V or floated) address electrodes during sustain discharge, where side I means threshold breakdown voltage (V_tXY) between X and Y electrodes, side II means threshold breakdown voltage (V_tAY) between A and Y electrodes, side III means threshold breakdown voltage (V_tAX) between A and X electrodes, side IV means threshold breakdown voltage (V_tYX) between Y and X electrodes, side V means threshold breakdown voltage (V_tYA) between Y and A electrodes, and side VI means threshold breakdown voltage (V_tXA) between X and A electrodes.

for MgO surface characteristics and PL (Photoluminescence) for analyzing the photo intensity emitted from the phosphor layers.

A. Monitoring of MgO Surface by AFM

Fig. 10 shows the changes in the two- and three-dimensional AFM images of MgO surface for the nondischarge and discharge regions. Like Fig. 9, the plasma discharge has not been produced in the nondischarge region, whereas the plasma discharge has been produced continuously for 850 hours in the discharge region under variously biased address electrodes, such as grounded and positive-biased or floated address electrodes. The roughness and morphology of the MgO surfaces in discharge regions were observed to be greater than those in the nondischarge region. This increased roughness and morphology for the discharge region were mainly due to the ion bombardment during the sustain discharge. As shown in Fig. 10, for the positive-biased or floated address electrodes, the MgO surface was more damaged or sputtered than that of

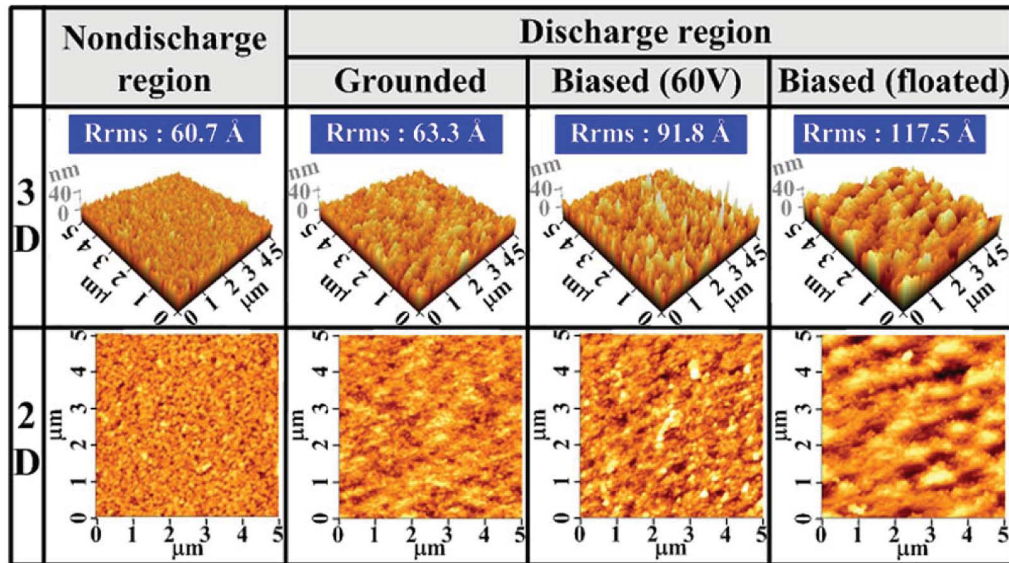


Fig. 10. Comparison of 2- and 3-D AFM images and roughness (Rrms) of MgO surface changes in nondischarge and discharge regions after 850 h-sustain discharge with grounded and positive-biased (60 V or floated) address electrodes.

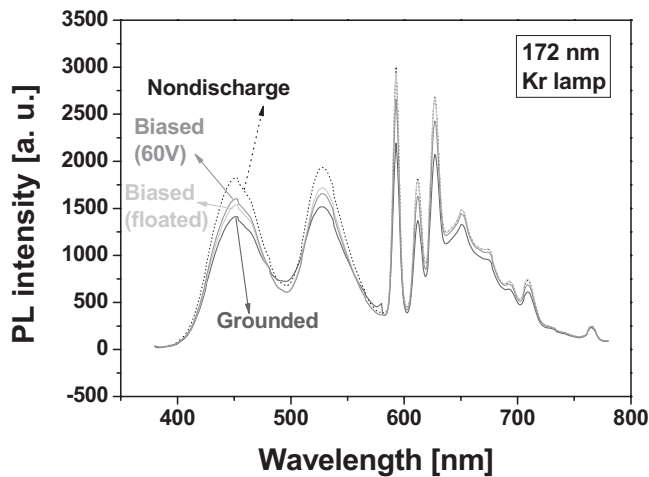


Fig. 11. Comparison of profiles of photo intensity (172 nm using Kr lamp) based on PL analysis of phosphor layer before and after 850 h-sustain discharge when using grounded and positive-biased (60 V or floated) address electrodes.

the grounded address electrode, implying that the Mg species were more sputtered from MgO layer due to the intense discharge produced by the positive-biased or floated address electrodes, as shown in Figs. 5 and 8(a).

B. Monitoring of Photoluminescence from Phosphor Layers

Fig. 11 shows the changes in the profiles of photo intensity (visible rays, 380~780 nm) emitted from the phosphor layers when the vacuum ultra violet (VUV, 172 nm using Kr lamp) irradiated the surface of the phosphor layers in the nondischarge and discharge regions after the 850 hour-sustain discharge under variously biased address electrodes, such as grounded and positive-biased or floated address electrodes using a PL analysis. As shown in Fig. 11, for the positive-biased or floated address electrodes, the difference of the PL

intensity emitted from the phosphor layers between the discharge and nondischarge regions was reduced in comparison with the grounded address electrode. The better permanent image sticking characteristics for the positive-biased or floated address electrodes 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 sustain waveform with positive-biased or floated address electrodes, the less deposit of Mg species on the phosphor layer was presumably due to more decrease in the crystallization of Mg species with the phosphor layer by suppressing the ion bombardment onto the phosphor in the case of adopting the positive-biased or floated address electrodes [11, 12]. In addition, this experimental result shows that a reduced light output could also mean an increased number of defects in the MgO deposited on top of the phosphor. As an MgO bandgap is 7.8 eV, an optical absorption starts at 7.65 eV. However, a photon energy of 172 nm is 7.2 eV, meaning that pure MgO crystals are transparent to 172 nm. Accordingly, unless the Mg species on the phosphor layer have lots of defects like F-centers etc., there should be no absorption by pure MgO crystals. 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. In addition, suppose that the Xe content would increase up to 20%, the ion bombardment onto the phosphor layer would be expected to be more severe, meaning that the applications of positive-biased or floated address electrodes would be still effective in blocking the ions incident on the phosphor layer. Hence, the application of positive-biased or floated address electrode suggested in this experiment would be expected to help reduce both the permanent and temporal [7, 15] image stickings, irrespective of the Xe partial pressure.

V. CONCLUSION

The effects of the types of different bias conditions of the address electrode during sustain discharge such as the grounded and positive-biased or floated address electrodes on the permanent image sticking were investigated. Our experiment showed that the positive-biased or floated address electrodes was more effective in suppressing permanent image sticking than the grounded address electrode during sustain discharge. By blocking the ion bombardment of the phosphor layer in case of adopting the positive-biased or floated address electrodes, the crystallization of Mg species with the phosphor layer was effectively minimized, thereby resulting in suppressing the reduction of the luminance. As a result, the positive-biased or floated address electrodes is confirmed to be a very effective method for reducing permanent image sticking. Thus, it is expected that the positive-biased or floated address electrodes during sustain discharge will help to reduce the permanent image sticking in ac PDP-TV.

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Choon-Sang Park received the M.S. and Ph.D. degrees in electronic and electrical engineering from Kyungpook National University, Daegu, Korea, in 2006 and 2010, respectively.

He was a Post-Doctoral Fellow with the School of Electrical Engineering and Computer Science, Kyungpook National University, from 2010 to 2011. Since 2011, he has been a Brain Korea 21 Research Professor with the School of Electrical Engineering and Computer Science. His current research interests

include microdischarge physics, MgO thin films, driving waveforms of plasma display panels, and surface analysis for new materials.



Heung-Sik Tae (M'00–SM'05) received the B.S., M.S., and Ph.D. degrees in electrical engineering from Seoul National University, Seoul, Korea, in 1986, 1988, and 1994, respectively.

He has been a Professor with the School of Electronics Engineering, College of IT Engineering, Kyungpook National University, Daegu, Korea, since 1995. His current research interests include optical characterization and driving waveforms of plasma display panels, design of millimeter wave guiding structures, and electromagnetic wave propagation using meta-materials.

Dr. Tae is a member of the Society for Information Display. He has been serving as an Editor for the IEEE TRANSACTIONS ON ELECTRON DEVICES section on display technology since 2005.