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ABSTRACT

The permanent image sticking phenomena were examined and compared for the two different barrier rib structures such as the single and double barrier ribs. To compare the permanent image sticking phenomena for both barrier rib structures, the differences in the display luminance, address discharge delay time, firing voltage, visible light profile, impulse, and SEM image of the image sticking cells during long time discharges were measured. The proposed double barrier structure showed that the variations in the surface states of the MgO layer remained almost the same between ITO and bus electrodes during long time discharges, thereby reducing the difference of the luminance and statistical address delay times. As a result, the double barrier rib structure was observed to mitigate the permanent image sticking in comparison with the single barrier rib structure in the 50 in full HD ac-PDPs with a He (35%)-Xe (11%)-Ne contents.

KEYWORDS

50 in full-HD AC-PDP panel; double barrier rib; permanent image sticking; luminance; firing voltage; formative address delay time; statistical address delay time; luminance profiles; impulse; Xe ion; front panel; rear panel

1. Introduction

Alternating-current plasma display panel (ac-PDP) is one of the promising high image flat panel display devices with the sizes larger than 50 inch diagonal, and as such under very active development for its application to full high-definition television (FHD TV). 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, 2] whereas image sticking means a permanent image sticking that is not recoverable in spite of severe treatment [3–7]. For the realization of the high-quality PDPs for reducing image sticking, many studies have so far been made on various parameters such as MgO [8], phosphor [9, 10], gas compositions[11], driving waveform [12–15], sealing method [16], and post treatment [17]. However, image stickings of cell geometry conditions have not yet been studied, particularly for FHD PDPs under various barrier rib structures.

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The sustain electrodes on the front panel of as-PDPs consist of two different conductors having different features, that is, one conductor is the indium thin oxide (ITO) electrode that has a good visible transmittance but a low conductivity, whereas the other is the bus electrode that has a good, conductivity but opaque optical property. Accordingly, the MgO surfaces on both the ITO and bus electrodes exposed to the discharge space would experience different ion bombardments during a long time discharge in the micro-discharge cells with conventional barrier rib structure. Our previous experiments have shown that the variations in the surface states of the MgO layer with respect to the ion bombardments during a long time discharge were very important for determining the luminance, color temperature, firing voltage, formative, and statistical address delay times [6–10]. These parameters act as significant factors in determining a degree of image sticking. In this sense, if the MgO surfaces experience similar ion bombardments during a long time discharge irrespective of the conductivity difference between the ITO and bus electrodes, the image sticking problems can be expected to be improved considerably. Our experiment will show that the proposed double barrier rib structure can locate a part of the bus electrode on the barrier rib for minimizing the ion bombardments toward the bus electrode, thereby resulting in improving the image sticking by further focusing the sustain discharge in the vicinity of the ITO electrode rather than bus electrode.

Accordingly, this study examines the effects of the changes in the barrier rib structure on the permanent image sticking characteristics by comparing the discharge characteristics produced under the single and double barrier rib structures in the commercial 50-in. FHD AC-PDP module with a He (35%)-Xe (11%)-Ne contents and box-type barrier.

2. Experiment set-up

Figures 1 (a) and (b) show the schematic diagram of a single pixel in the conventional single and newly proposed double barrier rib structures employed in this study. As shown in Fig. 1(a), the conventional barrier rib structure consisted of one barrier rib between the upper and lower discharge cells; it was hereinafter referred to as "single barrier rib stricture." In this case, the bus electrode was situated in discharge space. Whereas, as shown in Fig. 1 (b), the new barrier rib structure consisted of two barrier ribs between the upper and lower discharge cells for reducing the unnecessary discharge loss; it was hereinafter referred to as "double barrier rib stricture." In this case, a part of the bus electrode was situated on the barrier rib and exposed by about 25 μm in discharge space. A color analyzer (Konika Minolta, CA-100 plus), photosensor amplifier (Hamamatsu C6386), signal generator, and digital video photometer (DVP, PR-900) were used to measure the luminance, address discharge delay time, firing voltage, and visible light profile, respectively. The gas chemistry and pressure in the 50-inch full high-definition (FHD) panel were He (35%)-Xe (11%)-Ne and 420 Torr. To investigate permanent image sticking characteristics, the entire region of the 50-inch FHD test panel was changed to a full-white background immediately after displaying a square-type image at a peak luminance [4, 7, 10, 16, 17]. The sustain voltage and frequency for the sustain period were 205 V and 200 kHz, respectively. The duty ratio of the sustain pulses was 40% and the total display time was 1000 hours. A driving method with a selective reset waveform was also adopted. As shown in Fig. 1, the indium tin oxide (ITO) electrode had a low conductivity, whereas the bus electrode made from silver had a high conductivity. The gap between the two ITO electrodes was short, whereas the gap between the bus electrodes was long. The gap and width between the two ITO and bus electrodes, and detailed panel specifications for the two structures were exactly the same, except for the barrier rib structure in Fig. 1.

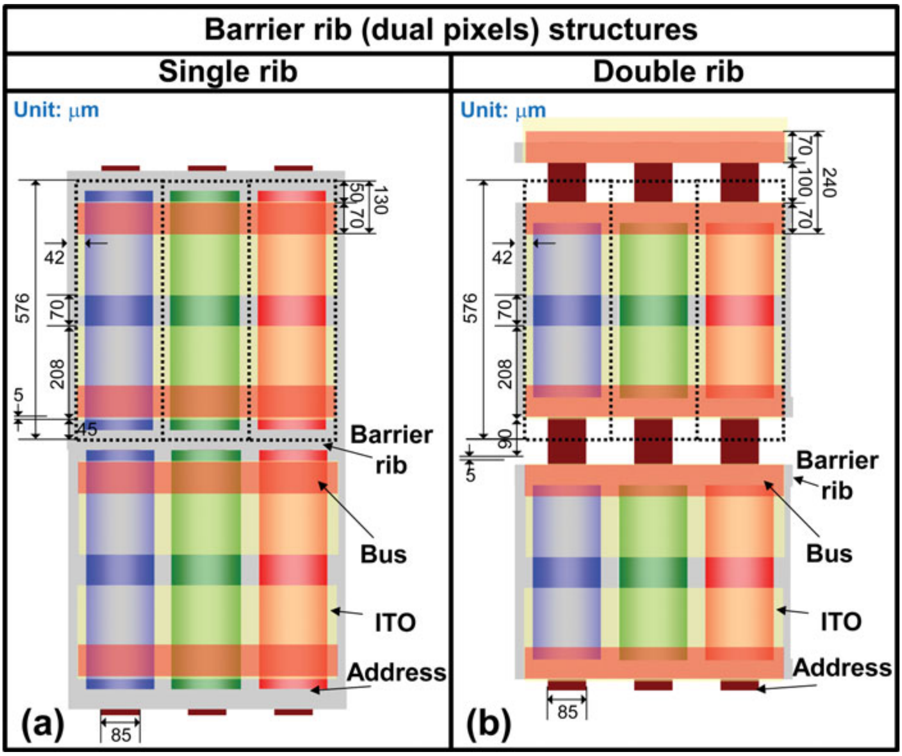


Figure 1. Schematic diagram of single (conventional) and double barrier rib (single pixel) structures in 50-inch FHD AC-PDP, including red, green, and blue cells.

3. Results and discussion

3.1. Monitoring of luminance, address discharge delay time, and firing voltage characteristics relative to 1000- hour display time

Figure 2 shows the changes in the luminance and the normalized luminance in the discharge region measured for up to 1000 hours on the 50-inch FHD test panel when adopting the single and double barrier rib structures. As shown in Fig. 2(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, a normalized luminance of 100 corresponds to no luminance difference between the before and after sustain discharges, implying no permanent image sticking [14]. In case of the double barrier rib structure, the initial luminance was decreased at the same sustain voltage level due to the reduction of discharge space. As shown in Figs. 2(a) and (b), when adopting the single barrier rib structure, the luminance difference and normalized luminance were remarkably reduced during the long time discharges. In the discharge region where a strong sustain discharge was repeatedly produced, Mg particles were sputtered from the MgO surface and phosphor layer was damaged due to the severe ion bombardment onto the MgO and phosphor layer. The resultant discharge degradation of the MgO and luminance degradation of the phosphor layer due to the ion bombardment was thus the major cause of permanent image sticking [9]. However, when adopting the double barrier rib structure, the luminance difference and normalized luminance were slightly reduced and improved in comparison with the single barrier rib structure. This indicated that the permanent image sticking was improved in the case of adopting the double barrier rib structure instead of the conventional single barrier rib structure.

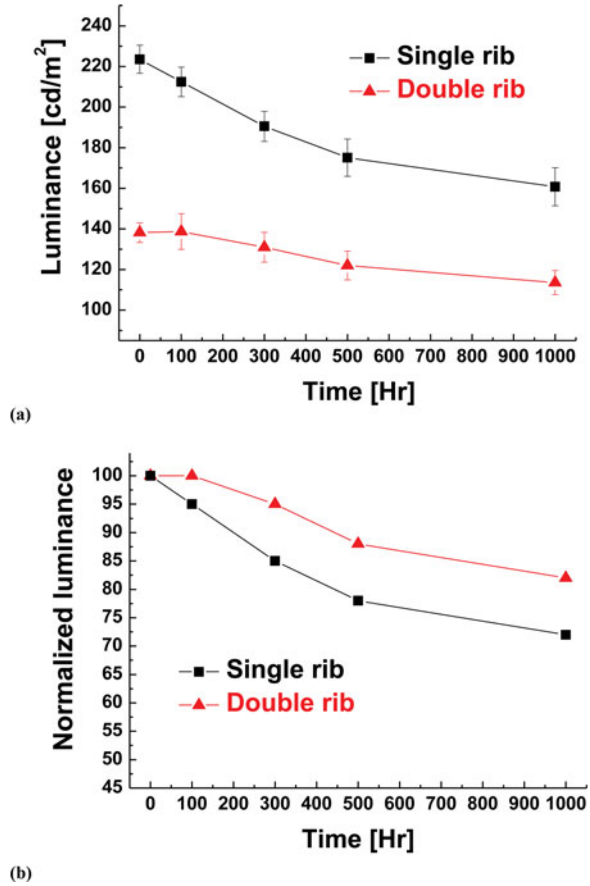


Figure 2. Comparison of (a) luminance and (b) normalized luminance relative to display time measured from 50-inch FHD panels when adopting single and double barrier rib structures.

Figure 3 shows the changes in the difference of statistical address delay time (ΔT_s) and total address discharge delay time differences (ΔT) in the discharge region measured for up to 1000 hours on the 50-inch FHD test panel when adopting the single and double barrier rib structures. As shown in Figs. 3 (a) and (b), when adopting the single barrier rib structure, the address discharge delay time differences were remarkably increased during the long time discharges; it was mainly due to the variations in the surface states of the MgO layer between on the ITO and bus electrodes with respect to the ion bombardments, thereby resulting in producing unstable discharge with increasing address discharge differences [18]. However, when adopting the double barrier rib structure, the address discharge delay time differences were slightly increased and improved in comparison with the single barrier rib structure; it was mainly due to the reduction of the variations in the surface states of the MgO layer between on the ITO and bus electrodes with respect to the ion bombardments, thereby resulting in reducing unstable discharge with decreasing address discharge differences. The detailed MgO surface variations will be shown in Fig. 5. This also indicated that the permanent image sticking was reduced and improved using the double barrier rib structure.

Figure 4 shows the changes in the firing voltage between the two sustain electrodes in the discharge region measured for up to 1000 hours on the 50-inch FHD test panel when adopting the single and double barrier rib structures. As shown in Fig. 4 for both cases, the firing voltages under MgO cathode conditions were slightly increased by about 5 V, and nevertheless the

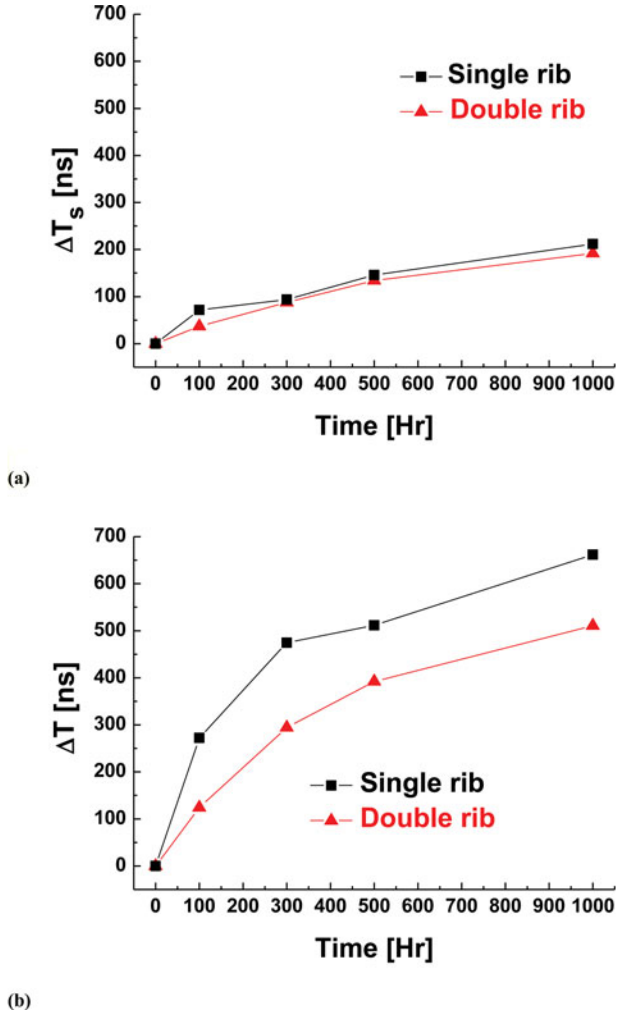


Figure 3. Comparison of (a) statistical address discharge delay time differences (ΔT_s) and (b) total address discharge delay time differences (ΔT) relative to display time measured from 50-inch FHD panels when adopting single and double barrier rib structures.

firing voltage differences were almost the same for both cases. Consequently, the firing voltages showed similar tendency for both cases, which meant that the firing voltage differences were not affected by the permanent image sticking in this experiment.

3.2. Analysis of image sticking induced by double barrier rib structure

(1) Monitoring of MgO surface characteristics

To investigate the reason for the enhanced permanent image sticking after the 1000-hour strong sustain discharge in the case of adopting the double barrier rib structure, the scanning electron microscopy (SEM) images were measured for the surface morphology of the MgO thin film positioned on the ITO and bus electrodes.

Figure 5 shows the changes in the plane-SEM images of the MgO surfaces on the ITO and bus electrodes in the discharge region after the 1000-hour strong sustain discharge on the 50-inch FHD test panel when adopting the single and double barrier rib structures. As shown

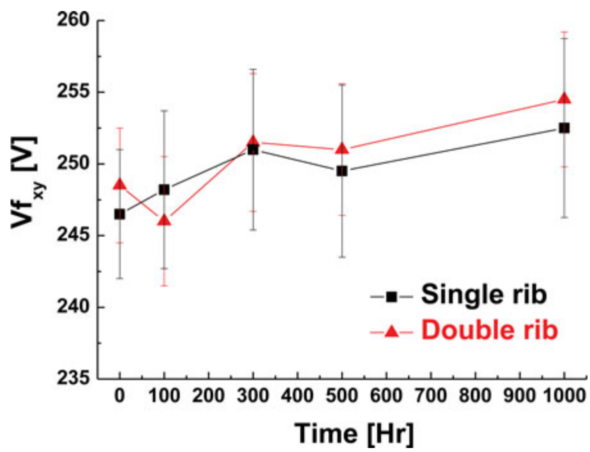


Figure 4. Comparison of firing voltages between two sustain electrodes (X and Y) relative to display time measured from 50-inch FHD panels when adopting single and double barrier rib structures.

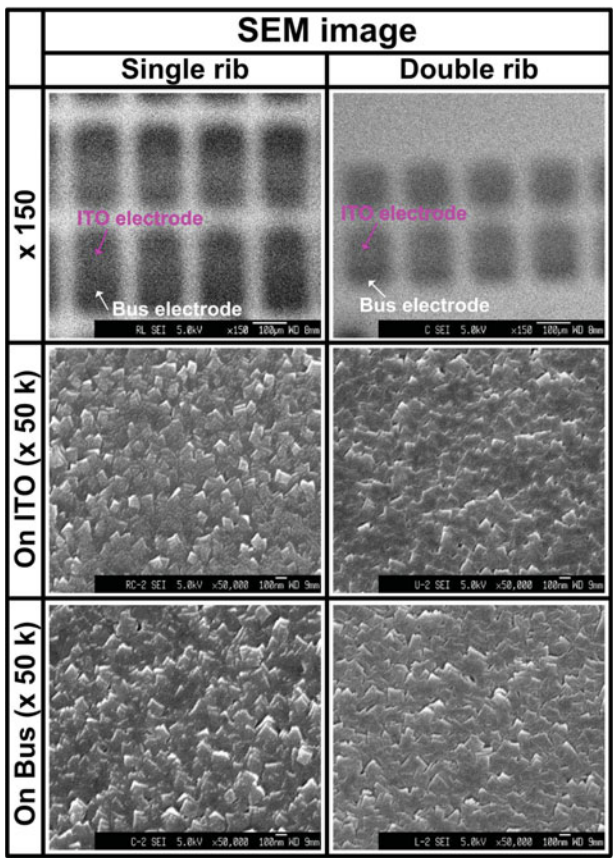


Figure 5. Comparison of SEM images of MgO surface changes on bus and ITO electrodes after 1000 hours strong sustain discharge measured from 50-inch FHD panels when adopting single and double barrier rib structures.

in Fig. 5, for the single barrier rib structure case, the MgO surface morphology on the bus electrode was observed to be larger than that on the ITO electrode, whereas for the double barrier rib structure case, the MgO surface morphologies for both ITO and bus electrodes were observed to be almost the same. The surface morphologies shown in case of the single rib structure of Fig. 5 confirm the MgO surface on the bus electrode was much more bombarded by the ions, compared to that on the ITO electrode. On the other hand, when adopting the double barrier rib structure, the MgO surface on both the ITO and bus electrodes was struck severely, implying that the strong discharge was produced on both the ITO and bus electrodes. These experimental results implied that the deteriorated permanent image sticking under single barrier rib structure could be attributed to the difference of the MgO surface morphologies between on the ITO and bus electrodes. In short, the variations in the surface states of the MgO layer with respect to the ion bombardments during a long time discharge were very important for determining the luminance and statistical address delay times. These parameters act as significant factors in determining a degree of permanent image sticking.

(2) Monitoring of luminance profiles in unit cells

Figure 6 shows the light patterns and three-dimensional (3D) luminance profiles, including red, green, and blue unit cells, during the strong sustain discharge on the 50-inch FHD test panel when adopting the single and double barrier rib structures using the digital video photometer with auto scale. Figure 7 also shows the light patterns, two-dimensional (2D) luminance profiles on green unit cell, and luminance difference on green cell. In case of the double barrier rib structure, the initial luminance was decreased at the same sustain voltage level in Fig. 2. Nonetheless, as shown in Fig. 7 (b) with same scale, when adopting the double barrier

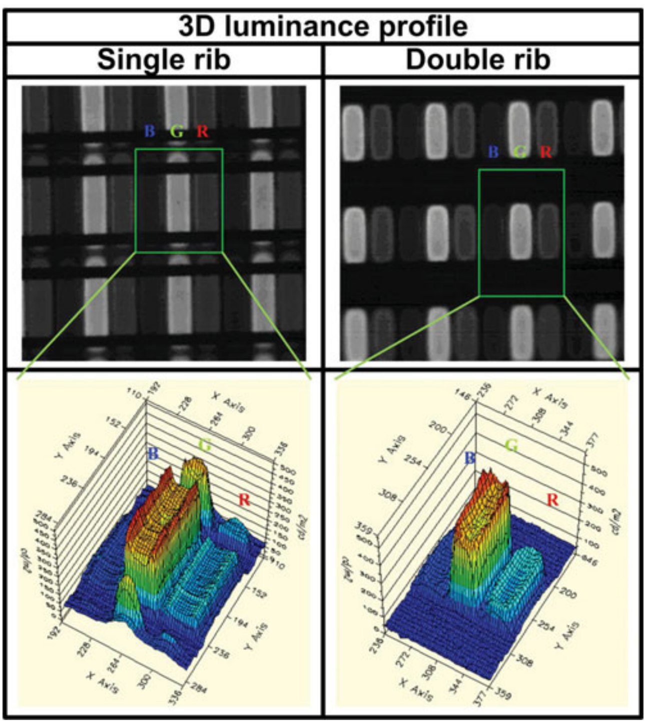


Figure 6. Light patterns and three-dimensional (3D) luminance profiles, including red, green, and blue unit cells, when adopting single and double barrier rib structures.

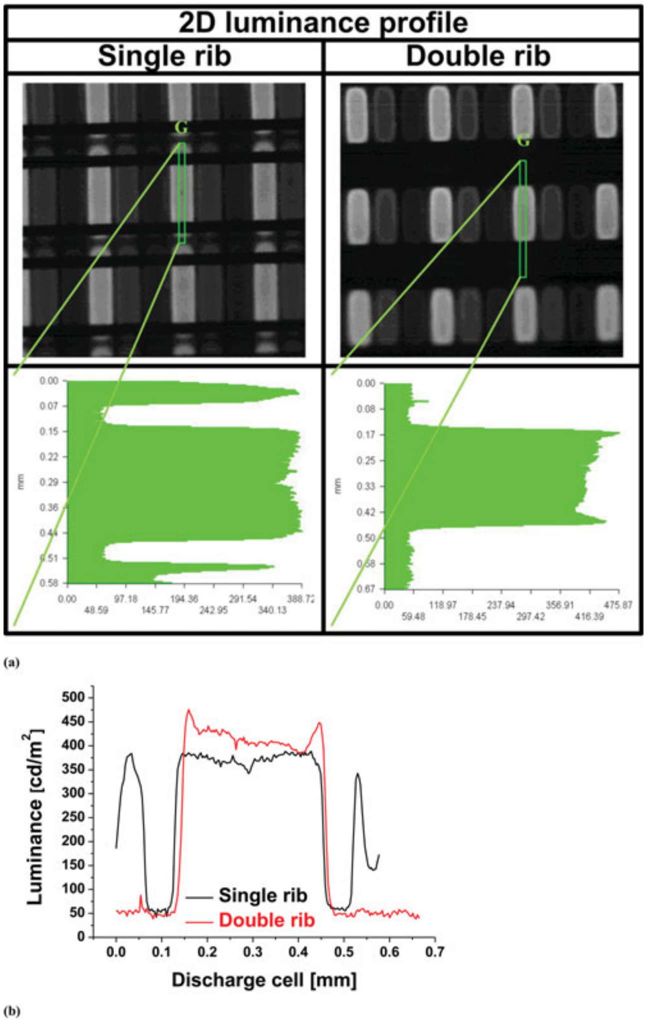


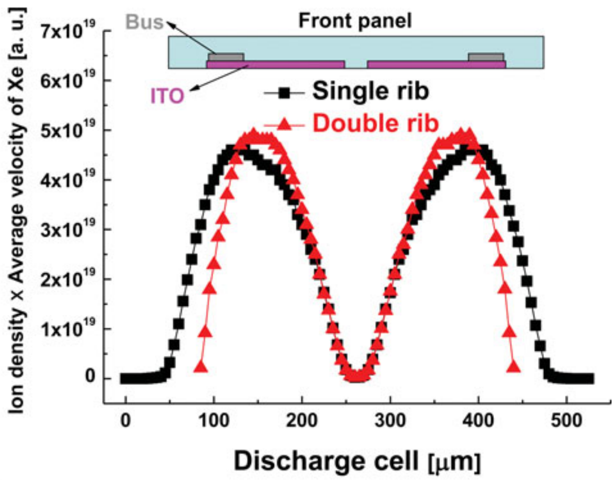
Figure 7. (a) Light patterns and two-dimensional (2D) luminance profiles on green cell, and (b) luminance differences on green unit cell when adopting single and double barrier rib structures.

rib structure, the luminance in unit cells was observed to be higher than that in the single barrier rib structure, implying the sustain discharge in unit cell was produced stronger in the case of adopting the double rib structure. Therefore, when adopting the double barrier rib structure, the MgO surfaces on both the ITO and bus electrodes were struck severely, as shown in the SEM image of Fig. 5. In other words, our experimental result confirms that the enhanced permanent image sticking under double barrier rib structure can be attributed to reducing the difference of the MgO surface morphologies on both the ITO and bus electrodes.

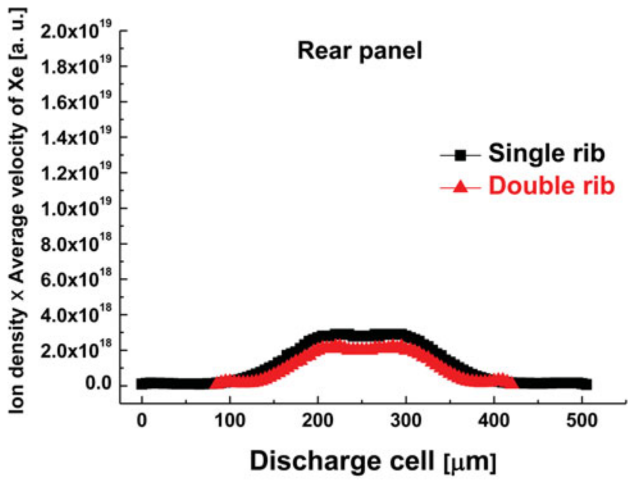
(3) Impulse of Xe ions near MgO surface along ITO and bus electrodes and phosphor surface along address electrode obtained from simulation

To identify the increase in the ion bombardment on the bus and ITO electrodes when adopting the double barrier rib structure during the strong sustain discharge, the 2D fluid model of plasma [19, 20] was used in this simulation.

Figure 8 shows the changes in the impulse of Xe ions near MgO surface along the ITO and bus electrodes on the front panel and the near phosphor surface along the address electrode



(a)



(b)

Figure 8. Comparison of impulse of Xe ions near (a) MgO surface along ITO and bus electrodes on front panel and (b) phosphor surface along address electrode on rear panel based on simulated results during strong sustain discharge when adopting single and double barrier rib structures, where impulse means ion density multiplied by average velocity.

on the rear panel based on the simulation during the sustain discharge when adopting the single and double barrier rib structures. As shown in Figs. 8 (a) and (b) for both cases in terms of similar scale, the impulse of Xe ions on the front panel was observed to be higher than that on the rear panel due to producing surface discharge mainly on the front panel in discharge cells. As shown in Fig. 8 (a), when adopting the double barrier rib structure, the impulse of Xe ions near MgO surface on the front panel was observed to be higher than that in the single barrier rib structure, and the impulse of Xe ions was almost the same for both the ITO and bus electrodes, thereby resulting in minimizing the difference of the MgO surface morphologies on both the ITO and bus electrodes. However, when adopting the single barrier rib structure, the impulse of Xe ions on the bus electrode was higher than that on the ITO electrode, which means that the MgO surface on the bus electrode was more damaged compared to that on ITO electrode. In this case, the MgO surface morphologies for both the

ITO and bus electrodes were observed to be quite different, as confirmed by the result of Fig. 5. In addition, as shown in Fig. 8 (b), when adopting the double barrier rib structure, the impulse of Xe ions near phosphor surface on the rear panel was observed to be lower than that in the single barrier rib structure, which resulted from the reduction of the ions bombarding toward the phosphor layer. The reduction of the ions bombarding toward the phosphor layer would be caused by producing surface discharge mainly on the front panel in case of adopting the double barrier rib structure, which is presumably due to the reduction in the ratio of the discharge space to the exposed electrode area. This result also illustrates that the double barrier rib structure can be effective in blocking the ions incident on the phosphor layer as well as minimizing the difference of the MgO surface morphologies on both the ITO and bus electrodes, thereby resulting in the reduction of permanent image sticking. Accordingly, the cell geometry adopting the double barrier rib structure proposed in this experiment would be expected to solve the permanent image sticking problem or to enhance the life time in the current PDP-TVs.

4. Conclusions

The effects of the types of different barrier rib structures such as the single and double barrier rib on the permanent image sticking phenomena were investigated. When adopting the double barrier rib structure, the impulse of Xe ions was almost the same for both the ITO and bus electrodes, thereby resulting in minimizing the difference of the MgO surface morphologies on both the ITO and bus electrodes. In addition, the double barrier rib structure can be effective in blocking the ions incident on the phosphor layer as well as minimizing the difference of the MgO surface morphologies on both the ITO and bus electrodes, thereby resulting in the reduction of permanent image sticking. As a result, our experimental results showed that the double barrier rib structure was more effective in suppressing permanent image sticking problem than the conventional single barrier rib structure, implying that the permanent image sticking problem strongly depended on the rib structure condition. Thus, it is expected that the double barrier rib structure will contribute to reducing the permanent image sticking of the ac PDP-TVs.

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