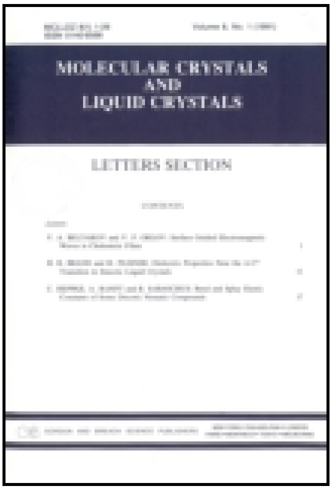

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Modified Driving Waveform for Ridged Dielectric Structure Based on V_t Closed Curve Analysis in AC PDP

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The discharge characteristics of an AC plasma display panel (PDP) with the ridged dielectric structure were investigated. In particular, characteristics such as firing voltage and related wall voltage based on the V_t *closed curve measurement were compared in the ridged and conventional dielectric structures. The front plate of the AC PDP with the conventional panel structure is composed of glass, electrodes and dielectric. In the ridged dielectric structure, the middle part of the dielectric layer is eliminated to allow for light to pass through more easily. This structural modification causes the plasma discharge between the two front electrodes to occur at a lower voltage. Meanwhile, as the ridged dielectric structure differs from the conventional dielectric structure, various problems arise if the conventional driving waveform is used. Especially, as the discharge firing voltage characteristics between the scan and sustain electrodes of the ridged dielectric structure is different, it is necessary to modify the reset and address waveforms accordingly. In this study, the* V_t *closed curves are investigated to compare the discharge firing voltages in the conventional and ridged dielectric structures. Based on the investigation, a modified driving waveform for the ridged dielectric structure was proposed. Using the proposed waveforms, the address discharge time of the ridged dielectric structure was reduced by approximately 200 ns.*

Keywords Ridged dielectric structure; wall charge; V_t closed curve; driving waveform; plasma display panel; PDP

1. Introduction

The AC plasma display panel (PDP) has been considered to be a suitable flat panel device for the 3D digital high definition television due to its advantages such as low manufacturing cost, simplicity of the manufacturing process for large size display, and high speed response time. Especially the high speed response time characteristic of the AC PDP gives it a large advantage over other display devices used for the 3D TV. On the other hand, the luminance and luminous efficiency of PDP is dramatically reduced when it is used for the 3D TV due to the nature of the principles of 3D display. This is the fatal drawback of PDP used for 3D

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Table 1. Specifications of the 42-in. AC-PDP used in this study

Front panel		Rear panel	
Sustain electrode width	110 um	Address electrode width	150 um
ITO width	360 um	Barrier rib width	60 um
ITO gap	85 um	Barrier rib height	120 um
Ne-Xe(15%) gas mixture			

TV. So far, most efforts to improve luminance and luminous efficiency of AC PDP have focused on improvement of the material, optimization of the discharge gas composition, development of the new driving method, and improvement of the discharge cell design [1] – [4].

Once the external voltages are applied to the AC PDP, the plasma discharge occurs inside the cell and vacuum ultraviolet (VUV) is generated. Visible light is produced when VUV excites the phosphor, and light is emitted through the front plate consisting of a dielectric layer, ITO and front glass. One of the methods to improve the luminance by altering the structural design of the discharge cell is to remove the unnecessary part of the dielectric layer in the front plate. In this ridged dielectric structure, the luminance would increase because the visible light produced from the phosphor would have to pass through only the glass. In addition, the sustain discharge between the two front electrodes would form more directly. Therefore, it was reported that this structure would also help to improve the luminous efficiency because the necessary voltage between the two front electrodes would be lower [6]. However, if the conventional driving voltage waveforms are applied to the AC PDP with the ridged dielectric structure, discharge misfiring may occur because the changed structure would have a different discharge firing voltage. In this study, wall voltage characteristics were analyzed based on the V_t closed curve in both the conventional and ridged dielectric structure, and a modified driving waveform suitable for the new structure was proposed.

2. Experiment

2.1. Panel Structure

The specification and schematic diagram of the panel used in this study are shown in Table 1 and Fig. 1A. 42-inch AC PDP was used, and Fig. 1 shows the cross-sectional views of the discharge cells for the (a) conventional and (b) ridged dielectric structures. The sustain (X) and scan (Y) electrodes were placed on the front plate side-by-side, and an address (A) electrode was placed on the rear plate in the direction vertical to the front electrodes. The middle part of the dielectric layer between the two electrodes on the front plate was removed in the ridged dielectric structure. Barrier ribs were omitted in these figures.

Normally, the dielectric layer is coated to protect the front electrodes in AC PDPs. The electrodes may become damaged if they are directly exposed to the strong plasma discharge that is generated in the cell by the external voltages applied. However, the amount of visible light leaving the front glass is decreased due to the dielectric layer. In order to solve this problem, a new panel structure called the ridged dielectric structure was designed in which

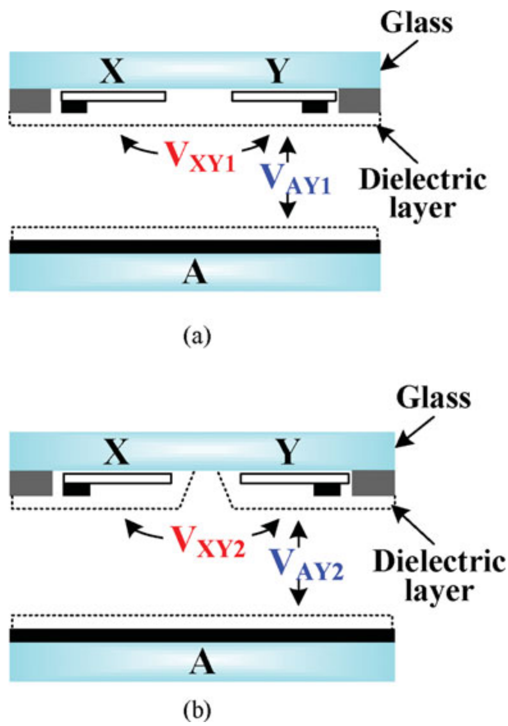


Figure 1. Schematic diagrams of the (a) conventional and (b) ridged dielectric structures.

the middle part of the dielectric layer between the two electrodes on the front plate is removed. This new structure is shown in Fig. 1(b) where the discharge space directly faces the front glass.

In the conventional dielectric structure, the plasma discharge is not directly produced between the two front electrodes – the surface discharge. It is spread across the discharge space and experiences a rather long discharge path because of the constant dielectric layer covering both the two front electrodes as shown in Fig. 1(a) [7]. However, in the ridged dielectric structure, about 60 μm of the dielectric layer between the two electrodes on the front plate is eliminated while other parts were kept the same as in the conventional structure. In this new structure, the plasma discharge between the two front electrodes would form more directly across the ridged gap of the dielectric. While the conventional dielectric structure needs a higher voltage to produce the sustain discharge because the two front electrodes are side-by-side, it is expected that the ridged dielectric structure would require a lower voltage to produce the plasma discharge between the two front electrodes because the triggering part of the discharge has a shorter path. In other words, the discharge firing voltage between X and Y electrodes would be lower.

Meanwhile, since the sustain discharge is mainly produced in the narrow area between the two front electrodes using low sustain voltage, if the conventional driving waveforms are applied to the ridged dielectric structure, this would give rise to some problems such as discharge misfiring or increase in address voltage. In this study, the conventional driving voltage waveforms were applied to the three electrodes in order to investigate the misfiring or unstable discharge firing, and the changes in the reset and address discharge characteristics were analyzed using V_t closed curve. In Fig. 1(a) and (b), V_{XY1} and V_{AY1} indicate the sustain

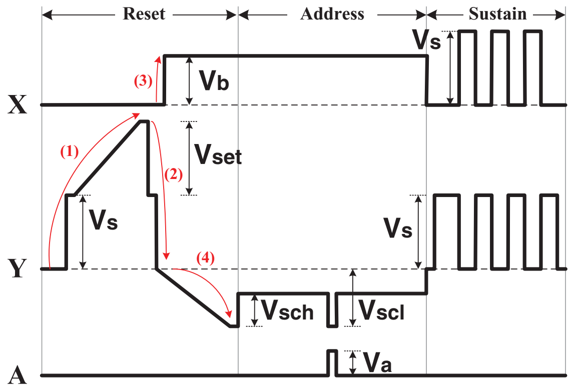


Figure 2. Conventional driving waveforms for the three electrodes during reset, address and sustain periods.

and address discharge firing voltages of the conventional structure, and V_{XY2} and V_{AY2} indicate those of the ridged dielectric structure.

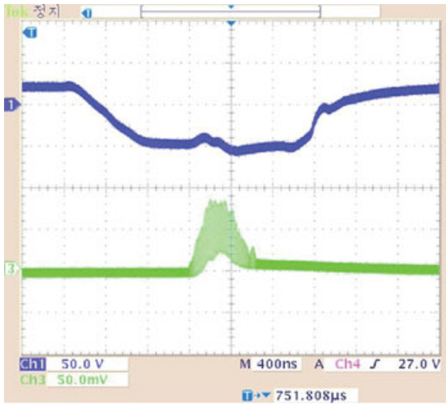
2.2. Conventional Driving Waveform

The conventional driving voltage waveforms applied to the conventional and ridged dielectric structures of the AC PDP are shown in Fig. 2. The driving waveforms for the AC PDP have several subfields during one TV frame, and each subfield consists of the reset, address, and sustain periods [8]. In the driving waveform for one subfield, when a gradually increasing ramp-type high voltage was applied to the Y electrode, a weak plasma discharge was induced in the cell and wall charge accumulated on the three electrodes. When a gradually decreasing ramp voltage was applied during the reset period, wall charge was redistributed among the three electrodes. During the address period, for those cells in which the scan and address pulses were applied simultaneously, the address discharge was selectively produced using the redistributed wall charge during the reset period. In consequence, those cells assigned to emit light accumulated wall charge and became ready for the sustain discharge. In the sustain period, the plasma discharge between the two front electrodes using the wall charge accumulated during the address period was maintained in the assigned cells, and visible light was emitted from the cells for the displaying image.

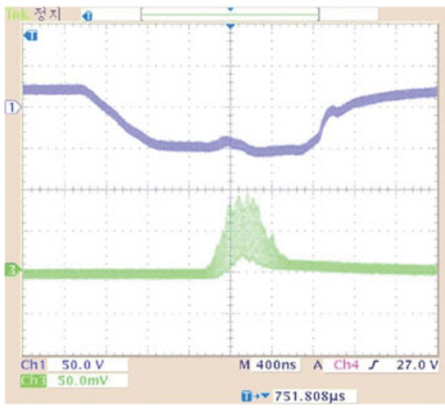
3. Results and Discussion

3.1. Measurement of Address Discharge Characteristics

The waveforms of the light emitted from the cells were measured using the conventional driving voltage waveforms to investigate the address discharge characteristics during the address period in both the conventional and ridged dielectric structures. Figures 3(a) and (b) show the waveforms of the light in the conventional and ridged dielectric structures when the scan and address pulses were applied. The upper waveform indicates the scan pulse and the lower waveform indicates the light waveform in each figure. The voltage waveforms shown in Fig. 2 were used in both structures except that V_b on the X electrode during the



(a)



(b)

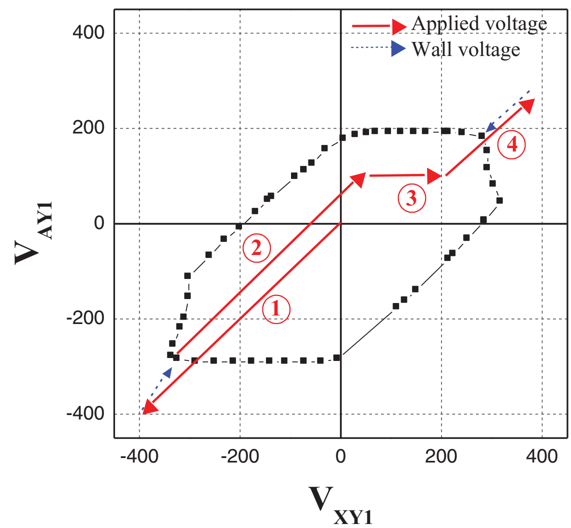
Figure 3. Comparison of the address light waveforms during the address period: (a) when the conventional driving waveforms with $V_b = 150$ V were applied to the conventional structure, (b) when the same waveforms with $V_b = 80$ V were applied to the ridged dielectric structure.

reset and address periods was set to 150 V in the conventional dielectric structure while it was set to approximately 80 V in the ridged dielectric structure. This reduction of V_b was necessary because discharge misfiring occurred when V_b of 150 V was applied to the new ridged structure. This indicates that the discharge firing voltage between the two front electrodes decreased by approximately 70 V in the ridged dielectric structure compared to the conventional structure.

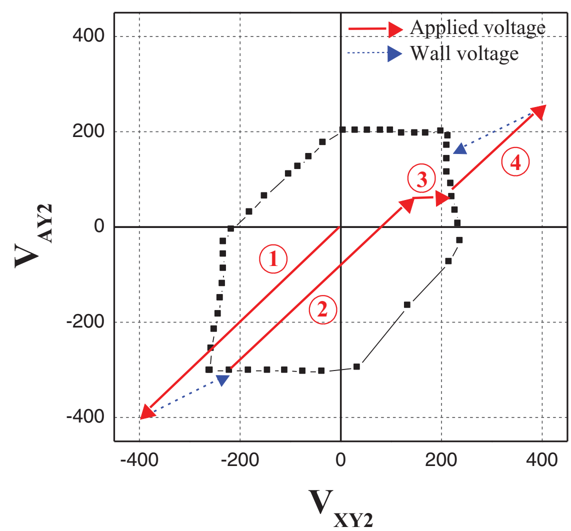
On the other hand, in Fig. 3(b), it was noticed that the address discharge start time between the Y and A electrodes during the address period was delayed in the ridged dielectric structure compared to the conventional structure. Also, unstable discharge was noticed on the oscilloscope screen in the ridged dielectric structure.

3.2. *Measurement of V_t Closed Curve and Analysis*

The V_t closed curve was measured to investigate the discharge firing voltages between the X-Y electrodes and the A-Y electrodes in the conventional and ridged dielectric structures,



(a)



(b)

Figure 4. Behavior of voltage vectors on the V_t closed curve when the conventional driving waveforms were applied to the (a) conventional and (b) ridged dielectric structures.

respectively [9]. Figure 4 shows the V_t closed curve measured in the (a) conventional dielectric structure and (b) ridged dielectric structure. V_{XY1} and V_{XY2} on the horizontal axes indicate the discharge firing voltages between the X and Y electrodes, and V_{AY1} and V_{AY2} on the vertical axes indicate the voltages between the A and Y electrodes. The locations of the dots on the top, bottom, left, and right sides of the boundaries were determined depending on whether the applied voltage differences between the electrodes were positive or negative. Comparing Figs. 4(a) and (b), the locations of the top and bottom dots were almost the same, whereas the locations of the left and right dots were noticeably different. The left and right dots indicate the discharge firing voltage between the X and Y electrodes. The discharge firing voltage between the X and Y electrodes of the ridged dielectric structure was clearly lower than that of the conventional structure.

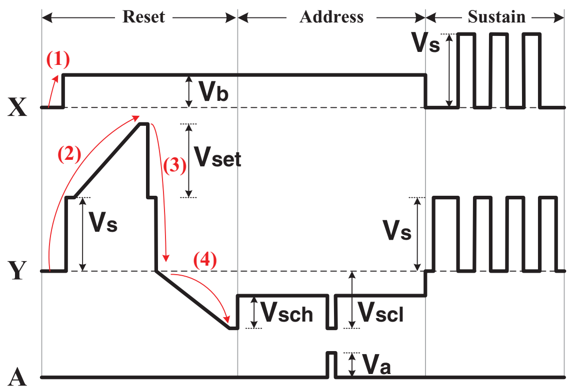
In Fig. 4, the solid arrows indicate the movements of the external voltages applied to the three electrodes during the reset period, and the dotted arrows indicate the changes of the wall voltages as the wall charge is redistributed due to the reset discharge [10]. The arrows labeled ① through ④ in Figs. 4(a) and (b) are the voltage vectors on the V_t closed curves corresponding to the voltage changes labeled by ① through ④ in Fig. 2. To elaborate, the voltage vector ①j corresponds to the rising ramp voltage on the Y electrode, the voltage vector ② to the voltage on the Y electrode coming down to the ground, the voltage vector ③ to the abruptly increasing voltage on the X electrode by V_b, and the voltage vector ④ to the falling ramp voltage on the Y electrode.

In the conventional dielectric structure, the discharge firing voltage between the A and Y electrodes was lower than that between the X and Y electrodes. Thus, the facing discharge occurred first as shown by the voltage vector ① and the dotted arrow on the V_t closed curve, and the wall charge accumulated on the A and Y electrodes as the rising ramp voltage was applied to the Y electrode in the reset period. After the wall voltage formed due to this wall charge, the voltage on the Y electrode was lowered to the ground and the voltage on the X electrode was raised. These changes corresponded to the movements indicated by the voltage vector ② and ③. These movements were located within the V_t closed curve. When the falling ramp voltage was applied to the Y electrode, weak discharge occurred in the cell. This change corresponded to the voltage vector ④ which left the boundaries of the V_t closed curve and the dotted arrow. Then, the voltages between the electrodes arrived at the upper-right corner on the V_t closed curve. After the reset period, if an address pulse was applied to the address electrode, the voltage vector moved in the upper vertical direction, and the address discharge was produced normally.

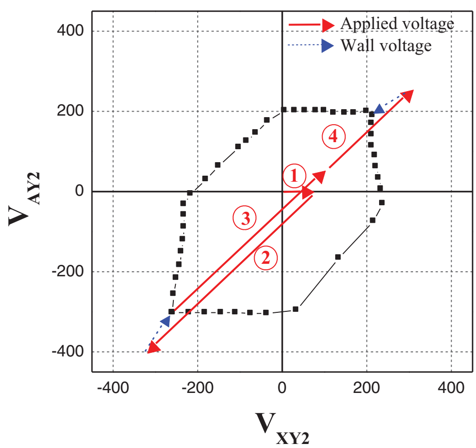
However, in the ridged dielectric structure, when the rising ramp voltage ③ was applied to the Y electrode, the discharge between the X and Y electrodes was produced first as shown in Fig. 4(b) instead of the discharge between the A and Y electrodes as in the conventional structure. In consequence, the amount of wall charge on the A and Y electrodes decreased. Furthermore, when the bias voltage V_b of 150 V used in the conventional structure was applied to the X electrode, the voltage vector ③ moved outside to the right of the V_t closed curve, and discharge misfiring occurred. Therefore, when the conventional driving voltage waveforms are adopted to the ridged dielectric structure, the bias voltage V_b should be decreased to about 80 V. Even when V_b of 80 V was used in the experiments, weak or unstable address discharge was noticed. This is because the final position of the voltage vector ④ on the V_t closed curve was lower than that of the conventional structure.

3.3. Modified Driving Waveform

For the ridged dielectric structure, the driving voltage waveform should be modified to facilitate the address discharge by enhancing the accumulation of wall charge on the A and Y electrodes during the reset period and to move the final position of the voltage vector ④ to the upper-right corner on the V_t closed curve. Fig. 5(a) shows the driving waveform modified for the improvement of the address discharge characteristics in the ridged dielectric structure, and Fig. 5(b) shows the externally applied voltage vectors and the wall voltage vectors on the V_t closed curve when the modified reset waveform is used. In order to improve the address discharge characteristics, V_b of low voltage was applied to the X electrode (①) even during the rising ramp voltage on the Y electrode such that



(a)



(b)

Figure 5. (a) Modified driving waveforms for the ridged dielectric structure and (b) the behavior of voltage vectors on the V_t closed curve.

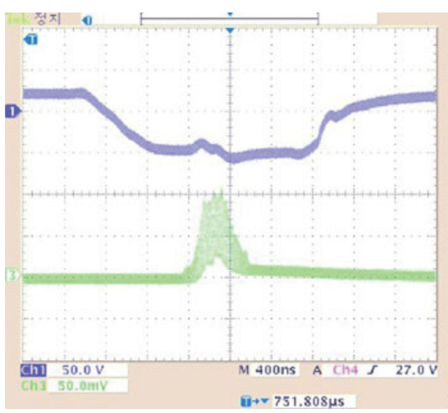


Figure 6. Address light waveform when the modified driving waveforms were applied.

Table 2. Comparison of V_b applied to the X electrode and the address discharge firing time in the conventional and ridged dielectric structures

Structure	Conventional	Ridged Structure	
Driving method	Conventional	Conventional	Modified
V_b [V]	150	80	80
Address discharge firing time [ns]	800	1000	780

it would prevent excessive discharge between the X and Y electrodes and promote the discharge between the A and Y electrodes. The voltage of V_b on the X electrode during the reset period was set to compensate for the lowered discharge firing voltage between the X and Y electrodes while keeping the same voltage between the A and Y electrodes. As shown in Fig. 5(b), voltage vector ① for 80 V first moved to the right on the V_t closed curve. Then the next voltage vector ② moved similarly to voltage vector ① in Fig. 4(a), corresponding to the rising ramp voltage on the Y electrode. Following voltage vector ③ and ④, the voltage vector moved to the upper-right corner of the V_t closed curve similarly to the case of Fig. 4(a). Because the voltage vector reached a similar position by the end of the reset period, the amount of wall charge accumulated was also similar and the address discharge characteristic was as good. Fig. 6 shows the measurement for the waveform of the light emitted from the cells of the ridged dielectric structure using the modified driving voltage waveforms. It was found that the address discharge characteristic of the ridged dielectric structure using the modified driving voltage waveforms was improved compared to the case in Fig. 3(b) where the conventional driving voltage waveforms were used. The address discharge firing time became almost the same as in the case of Fig. 3(a) where the conventional driving voltage waveforms were applied to the conventional dielectric structure. V_b used on the X electrode and the measured address discharge firing time were compared in Table 2. When the conventional driving voltage waveforms were adopted to the ridged dielectric structure, the address discharge firing time was delayed compared to that of the conventional structure. However, when the modified driving voltage waveforms were used, it was improved by about 200 ns.

Conclusion

Our experiments verified that the address discharge firing time was delayed when applying the conventional driving voltage waveforms to the ridged dielectric structure. From the measured V_t closed curve, it was noticed that the discharge firing voltage between the X and Y electrodes of the ridged dielectric structure was lower than that of the conventional structure. The low discharge firing voltage between the X and Y electrodes caused excessive discharge between the X and Y electrodes and insufficient discharge between the A and Y electrodes during the reset period. The insufficient discharge resulted in insufficient accumulation of wall charge on the X and Y electrodes at the end of the reset period. In this paper, the driving voltage waveform on the X electrode during the reset period was modified to compensate for the reduced accumulation of wall charge between the A and Y electrodes in the ridged dielectric structure. Consequently, the address discharge firing time of the ridged dielectric structure was reduced by approximately 200 ns compared to when the conventional driving voltage waveform was used.

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