The Effect of MgO Rate Preparing Conditions and Xe Partial Pressure on the Relative Life time of an AC Plasma Display Panel

Cha-Soo Park*, Min-Seok Choi, Joon-Young Choi***, Dong- Hyun Kim***, Ho- Jun Lee*** and Chung-Hoo Park*****

Abstract - This paper proposes a relative lifetime test method of MgO thin film. The suggested test conditions are 50℃, 400Torr, 20% over-voltage and 300㎑. The relative lifetime of MgO thin film is significantly affected by the MgO preparing conditions and Xe partial pressure. As result, the lifetime of the AC plasma display panel (PDP) is increased with an MgO thickness of 2000Å to 8000Å but is saturated over 5000Å (up to 9000 Å). In addition, as Xe partial pressure increases, AC PDP lifetime increases.

Keywords: ac AC PDP, accelerated lifetime test, MgO thin film, high Xe percentage

1. Introduction

With The rapid progress in the information industry has led to a continuous increase in the demand for new display devices with large size, high information capacity, and high resolution. Moreover, to compete with CRT (cathode ray tube) displays, various flat display devices have been developed and improved [1–2].

Nevertheless, AC PDP lifetime should be guaranteed over 30,000 hours, but no generally accepted data or diagnostic and estimating techniques exist for determining the relative lifetime of the AC PDP [3].

To improve the lifetime of the AC PDP, a fast relative lifetime diagnostic method should be developed. In this case, the relative lifetimes of various PDPs with test components are needed instead of evaluating the absolute lifetime, which is too long to facilitate such a study. If different two kinds of AC PDPs are studied, the lifetime can be improved by comparison.

In this study, we suggest a fast lifetime diagnostic method. We also discuss the effect of MgO thin film, the most important factor in determining the lifetime of the AC PDP. Moreover, another factor in determining the lifetime of the AC PDP, the Xe partial pressure is selected in Ne+He+Xe working gas.

2. Factors affecting the lifetime of the AC PDP

The lifetime of the AC PDP is correlated with many factors as shown in Table 1.

The most important factor affecting the lifetime of the AC PDP may be the lifetime characteristics of the MgO thin film because the MgO surface practically plays the role of discharge electrode.

Table 1 Factors affecting the AC PDP lifetime

Factor	Parameter
MgO	1) Deposition process (E-Beam, Sputtering, Ion Plating)
	2) Optimum thickness
	3) Surface morphology, density, orientation
	4) Substitute material condition
	5) Sputtering rate
Working-gas	1) Gas species
	2) Gas pressure
	3) Impurity gas in the manufaturing and discharge process
Dielectrics	1) Void partial discharge and breakdown
	2) Impurity gas in void
Phosphor	1) Deterioration by heating process and discharge plasma
	2) Deterioration by plasma sputtering
	3) Deterioration by MgO sputtering
Rib height	1) Discharge stability
	2) Heating and light loss

2.1 General fast lifetime test method

Three methods have been proposed and used to test the lifetime of the AC PDP: over-voltage text, over-temperature test, and high-frequency test. However, these tests are imperfect, causing a rise in temperature, breakaway from the normal driving voltage, and occurrence of self-erasing discharge of the panel [6]. Therefore, in this study, the short-term accelerating relative lifetime test method by high voltage and high frequency is suggested.

2.2 Accelerated relative lifetime test

The most important problem is the bombardment of positive ions on the MgO surface, which decreases the secondary electron emission coefficient and raises the firing

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voltage, and thus decreases the lifetime [7].

The sputtering rate, R, may be expressed as

$$R = k\left(\frac{JT}{P}\right)^{\alpha} \bullet f \tag{1}$$

where k is proportional const., J is the discharge current density, T is the surface or ambient temperature, P is the gas pressure, and f is the applied voltage frequency. If the sputtering rate increases, the period of relative lifetime test can be reduced in comparison with the real lifetime test. The relative lifetime can be controlled by main parameters such as J, T, and f.

2.2.1 Discharge current density

Discharge current density (J) can be controlled by the applied pulse voltage under driving condition of AC PDP as shown in Fig. 1 [8].

When the test is performed with some over-voltage, at first the displacement current flows during the pulse rising time and then discharge is ignited. At this point, wall charges can accumulate on the electrodes so that cells are turned off.

If the over-voltage is set too high, self-erasing is generated at the pulse falling time, causing the loss of wall charge. The gap voltage is given by

$$V_G = V_S + V_W \tag{2}$$

where V_G is gap voltage, V_S is sustain voltage, and V_W is wall voltage. If self-erasing occurs, V_W as well as V_G will decrease. Therefore, the over-voltage must be set up within limits so that self-erasing is avoided.

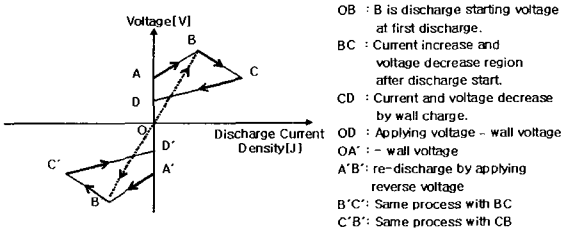

Fig. 1 J–V characteristic in the AC PDP

2.2.2 Frequency of the applied voltage

In AC PDP, discharge is generated for each alternate pulse, and the sputtering rate increases according to the frequency of applied pulse. Therefore, to take an accelerating lifetime test, the frequency of the sustain voltage must be higher than normal frequency.

Generally, the sustain time of the discharge current is about 2 μs, so the limit of maximum frequency is given by

$$f = \frac{1}{2\,\mu s} = 500\ kHz \tag{2}$$

Therefore 200–400kHz is suitable for the accelerating frequency.

2.3 Relationship between panel surface temperature and self-erasing

If surface temperature increases, the priming particles and wall charge are activated. Fig. 2 shows the self-erasing phenomena under the main discharge process. This phenomenon disturbs accelerated test conditions by erasing the wall charges. Therefore, maintaining a constant panel temperature during the lifetime test is necessary.

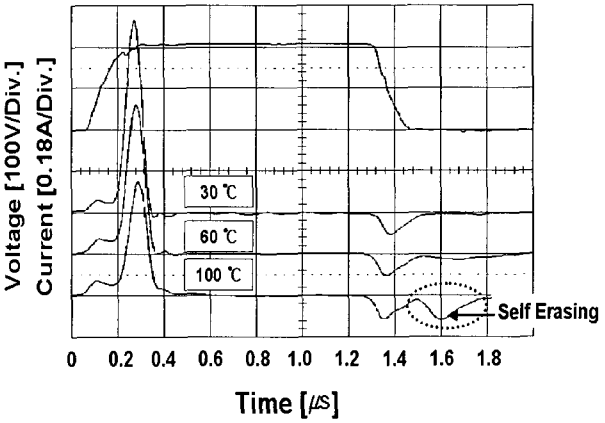

Fig. 2 The current waveform according to ambient temperature

2.4 Relationships between test frequency and self-erasing voltage

If the panel temperature T is 100 ℃, the discharge voltage showing the self-erasing phenomena at high frequency is too low to test the PDP with normal driving voltage. Therefore, F or T should be decreased.

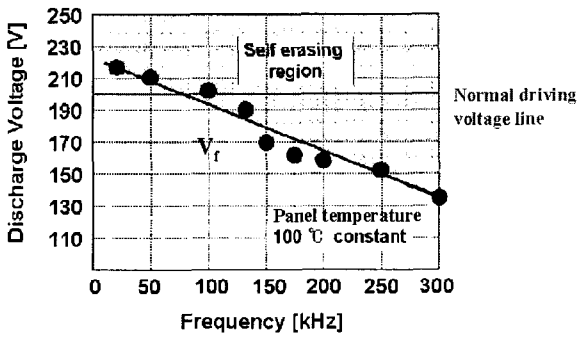

Fig. 3 Self-erasing region as a parameter of test frequency at 100℃

2.5 Self-erasing voltage at 300㎑ as a parameter of the temperature

For normal driving to be possible at high frequency without self-erasing, ambient temperature must be decreased. Fig. 4 shows a variation of self-erasing voltage according to the ambient temperature; self-erasing voltage varies inversely with the ambient temperature.

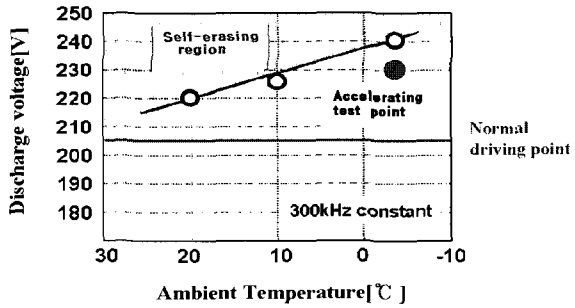

Fig. 4 Self-erasing region at 300kHz and operating temperature

2.6 Accelerated lifetime testing method in this study

According to the previously mentioned theory and investigation, the accelerated lifetime testing method suggested in this study has the following parameters: surface temperature of panel is 50℃, accelerating frequency of 300kHz, over-voltage by 20% of initial driving voltage ($(V_f+V_s)/2$), and working-gas pressure of 400Torr.

3. Experimental Set-Up & Method

3.1 Experimental set-up: Preparation of test panel

Table. 2 shows the specification of the four-inch test panel. Metal electrodes (fence) are present on the front glass and are coated with a dielectric layer. On the dielectric layer, a protectve layer of MgO thin film is deposited by E-beam evaporation method.

Table. 2 Specification of four-inch test panel (VGA type)

Working-gas : He+Ne(30%)+Xe(4%) 400Torr			
Front panel		Rear panel	
Thickness of dielectric layer	30㎛	Width of address electrode	100 ㎛
electrode Width	310 ㎛	Thickness of white back	20 ㎛
Electrode gap	60 ㎛	Height of rib	130 ㎛
Pitch of rib	360 ㎛	Width of rib	60 ㎛

Stripe-type address electrodes are arranged on the other rear glass. These address electrodes are coated with a white dielectric layer. 130㎛-high striped barrier ribs are made by the sandblaster technique are located on both sides of the address electrodes to separate the adjacent discharge cells and to eliminate optical cross-talk between cells.

Finally, phosphor is deposited on the rear. The test panel is annealed at 350℃ for three hours before the sealing process. With high-temperature annealing, gas impurities can be decreased.

As shown in Fig. 5, the electrodes of the panel are connected to the driving circuit. The waveform measurements, such as applied voltage and current, are carried out using a digital storage oscilloscope and current probe. Luminance is measured with a luminance colorimeter (BM7). The surface temperature is continuously measured by a thermo couple-digital display.

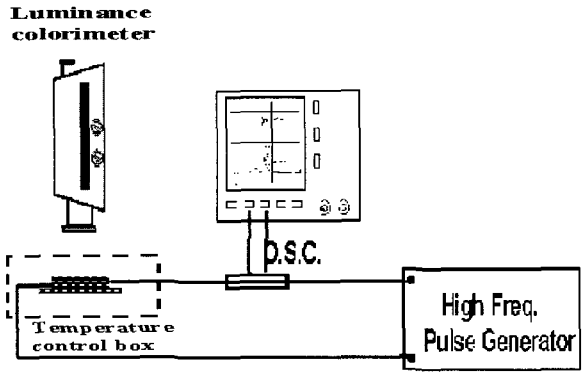

Fig. 5 Schematic diagram of experimental set-up

3.2 Experimental method

3.2.1 Driving conditions of the accelerated lifetime

The high frequency test is selected for a short-term lifetime test. In this case, the frequency of the applied voltage is 300kHz and the test voltage is 20% higher than the normal driving voltage.

To solve the problem of rising temperature, the experiment is conducted on the heatproof plate and one pair (three-line) of all six pairs on the test panel has been selected. The number of discharge cells is 350 at one pair. So, the panel surface temperature is constantly maintained at 50℃ at 300kHz.

3.2.2 End point of the accelerated lifetime test

The lifetime test end point is defined as the time when the luminance of the panel is decreased to half of its initial value under normal driving conditions. At the end point, the accelerated test time can be regarded as the relative lifetime of the AC PDP.

The acceleration tests are done with accelerating test

conditions, 200V with 300 ㎑ at 50℃ of panel surface temperature, but we regularly measure the luminance and sustain voltage under normal driving condition, 160V with 50 ㎑ at room temperature.

4. Result & Discussion

4.1 The relationship between MgO thickness and the relative lifetime of the AC PDP

We regularly measured values of firing (V_f) and sustain voltage (V_s) at 50kHz as shown in Fig. 6 whereas the test panel, which has an MgO thickness of 2000Å, has been accelerated under 300kHz, 200V, and surface temperature 50℃.

The luminance line in Fig. 6 is an appraisal standard of the relative lifetime of the AC PDP. If we define the lifetime of the panel as the time when the luminance decreases to half its initial value, it can be said that the lifetime of this sample is 25 hours under the condition of the accelerated lifetime test.

Figs. 7 and 8 show the characteristics of discharge voltage and luminance of the sample having an MgO thickness 5000Å and 8000Å, respectively. The lifetimes are estimated to be 25, 85, and 97 hours for each panel.

Discharge voltage rises during the lifetime test due to the MgO degradation caused by sputtering and due to the effect of impurities released during the discharge in the panel.

The impurities are generated by the residual contamination in cells during the exhaust process from working-gas, rib, frit glass, and heated phosphor or MgO thin film.

A small number of impurities can be incorporated into the MgO film during the deposition process, and these impurities can be released in the form of H_2, CO, or CO_2. For example, CO is electro-negative [9]. These gases capture electrons during the discharge process and the discharge voltage rises.

The protecting layer (MgO) can itself be degraded by sputtering and can also cause the degradation of the phosphor layer since parts of the sputtered atoms from the protecting layer are attached to the phosphor layer.

The crystalline quality of MgO film is assumed to inprove as it matures and the property of sputter-resistance may be improved. Therefore, high luminance can be maintained for a long time.

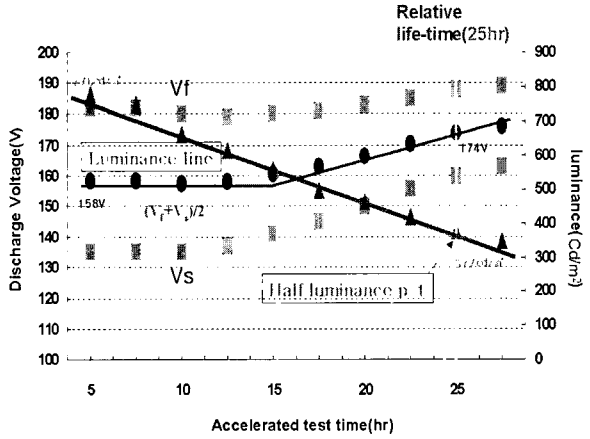

Fig. 6 Characteristics of discharge voltage and luminance after lifetime test for 2000Å of MgO thickness (208Å/min) at 50kHz

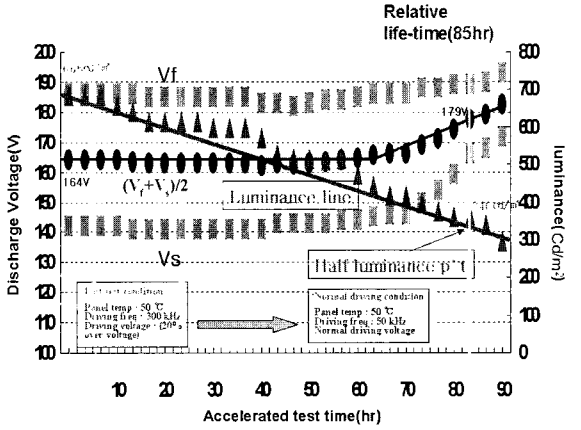

Fig. 7 Characteristics of discharge voltage and luminance after lifetime test for 5000Å of MgO thickness (208Å/min) at 50kHz

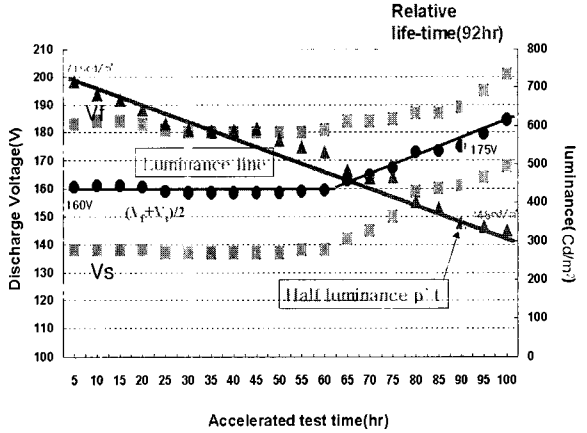

Fig. 8 Characteristics of discharge voltage and luminance after lifetime test for 8000Å of MgO thickness (208 Å/min) at 50kHz

Fig.9 shows the SEM photos of the MgO surface on a test panel of 8000Å thickness after the lifetime test. As shown in the figure, the surface of the MgO thin film is eroded by the sputtering of discharge plasma and is formed the shape of island. The crystallized part during the formation of MgO is supposedly left alive and the amorphous part is eroded.

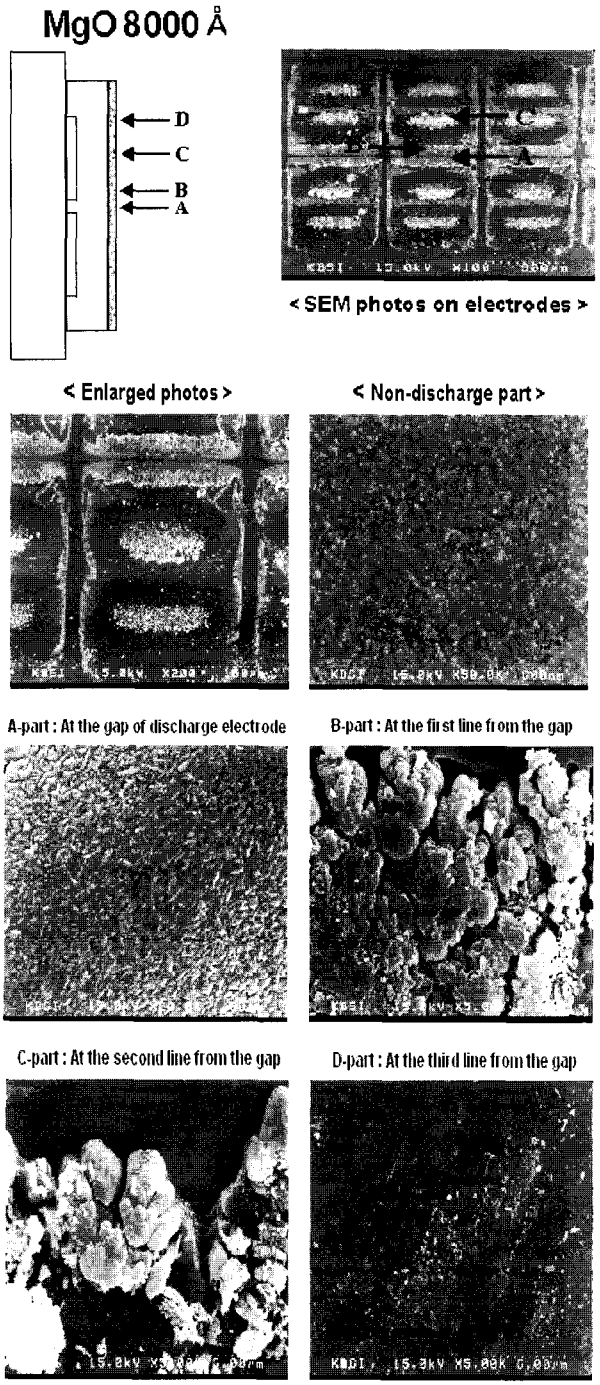

Fig. 9 SEM photos of MgO surface for 8000Å after accelerated lifetime test

Fig. 10 shows the relationships between MgO thickness and AC PDP relative lifetime.

The results are as follows.

(1) The lifetime was increased with MgO thickness but almost saturated over 5000Å.

(2) As MgO thickness increases, the decrease rate of luminance decreases; thus, high luminance can be maintained for a long time.

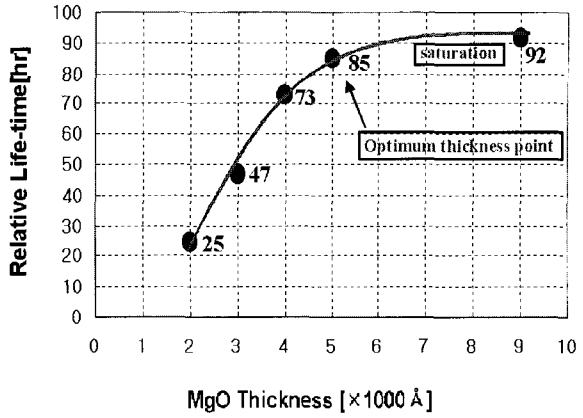

Fig. 10 Relative lifetime as a parameter of MgO thickness

4.2 The relationships between MgO deposition rate and AC PDP relative lifetime

Figs. 7 and 11 show the degradation characteristics of panels that have the same 5000Å MgO thickness but different deposition rates. The deposition rate of sample A is 625Å/min and of sample B is 208Å/min.

The measured relative lifetimes of sample A and B are 67 and 85 hours, respectively, under the condition of the accelerated relative lifetime test.

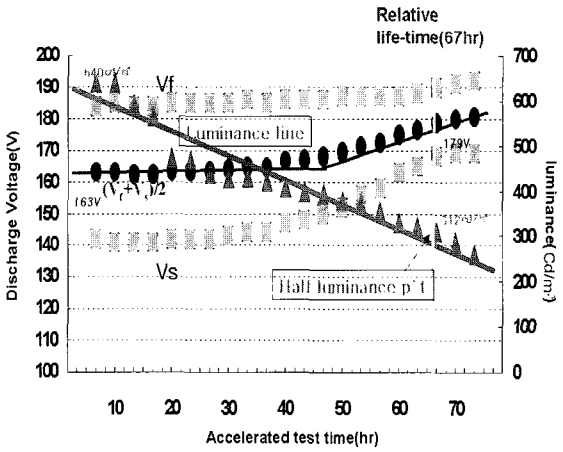

Fig. 11 Characteristics of discharge voltage and luminance after lifetime test of the deposition rate of MgO: 625Å /min (5000Å)

If the MgO deposition rate is increased by E-beam power, numerous evaporated MgO particles are accumulated in a short time. Then, the MgO film has a porous (which leads to amorphous) composition, and the adhesive force of the MgO film to the dielectrics gets worse.

On the contrary, by decreasing the MgO deposition rate, , the MgO film will be dense, which leads to a crystal composition. Therefore, the relative lifetime of crystallized MgO film is improved as shown in Fig. 12.

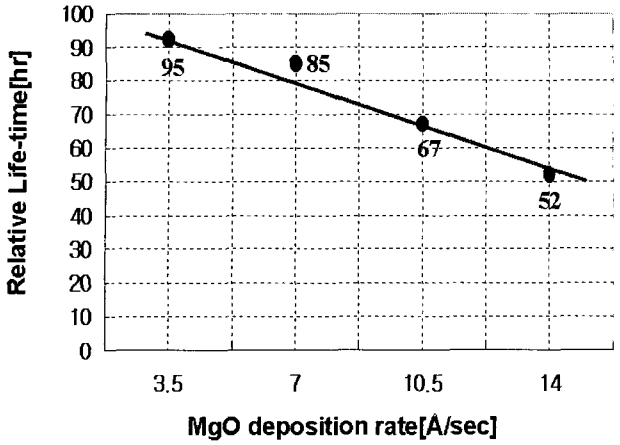

Fig. 12 Relative lifetime as a parameter of the MgO deposition rate

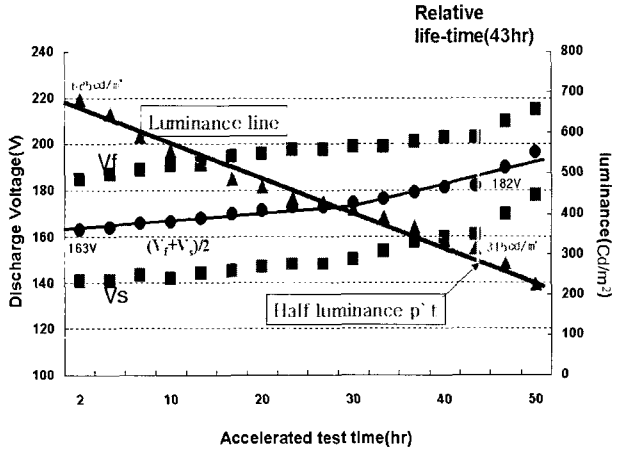

Fig. 13 Characteristics of discharge voltage and luminance after the lifetime test of Xe partial pressure: Xe 4%, Ne base

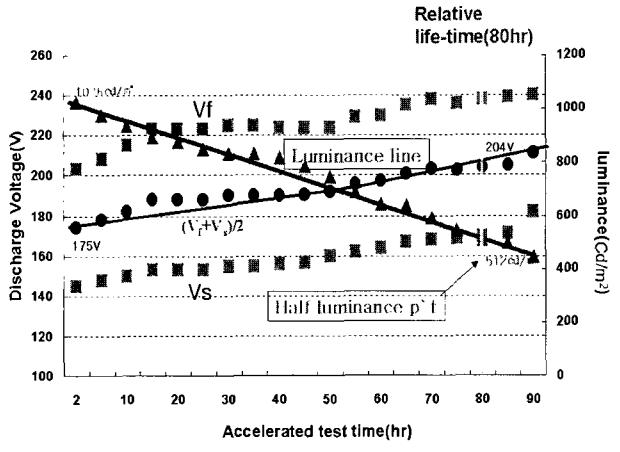

Fig. 14 Characteristics of discharge voltage and luminance after the lifetime test of Xe partial pressure: Xe 10%, Ne base

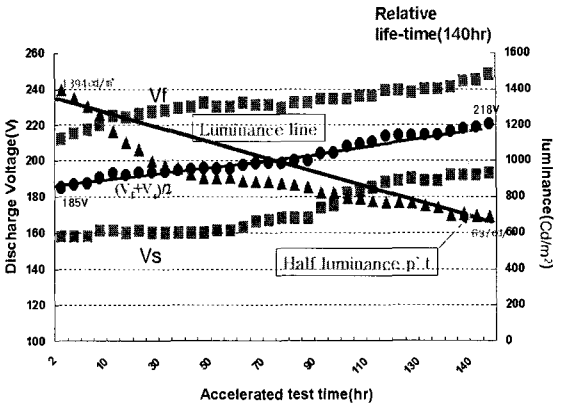

Fig. 15 Characteristics of discharge voltage and luminance after the lifetime test of Xe partial pressure: Xe 15%, Ne base

4.3 The relationships between Xe partial pressure and the relative lifetime of AC PDP

Figs. 13, 14, and 15 show degradation characteristics of the panels, which have the same MgO thickness of 5000 Åand the same deposition rate but various Xe percentages. The Xe percentage is 4%, 10%, and 15%, respectively, and the relative lifetimes of the panels are 42, 80, and 140 hours, respectively.

The calculated sputtering yield of MgO for Ne^+ and Xe^+ is plotted as a function of incident ion energy in Fig. 16.

The sputtering yield of Ne^+ can transfer its energy effectively to Mg or O by the small mass difference in these interacting particles [10], and this is probably the main reason the lifetime increases with increasing Xe partial pressure as shown in Fig. 17.

Another possible pathway for increasing the lifetime is reduction of incident energy Ne^+ due to large collision cross-section of the Xe atom. Therefore, the the lifetime is increased with Xe partial pressure for the following reasons.

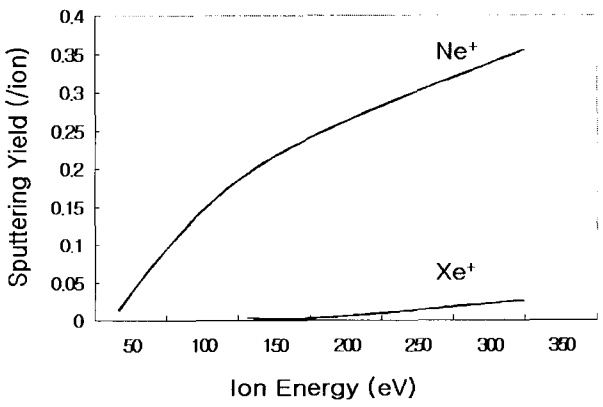

Fig. 16 Calculated sputtering yield of MgO for Ne^+ and Xe^+ as a function of incident ion energy

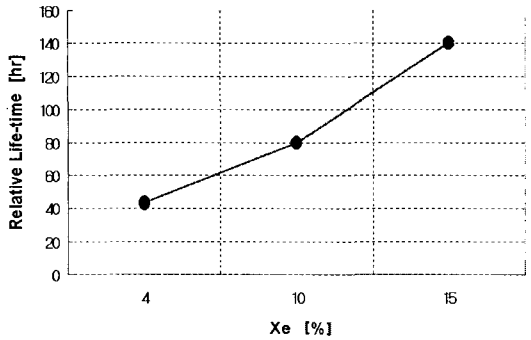

Fig. 17 Relative lifetime as a parameter of Xe partial pressure

1. Xe does not move easily and hinders the Ne^+ flow.

2. Xe suppresses MgO sputtering by Ne^+. That is, the sputtered MgO/Mg goes back to the MgO thin film, just like Ar in light bulk.

5. Conclusions

In this study, the accelerated relative lifetime tests are performed under the various conditions. The relationships between MgO deposition conditions and the AC PDP lifetime are investigated, and the effects of Xe partial pressure on the AC PDP lifetime are studied. The results may be summarized as follows.

(1) The suggested conditions for the short-term accelerating lifetime test are a panel surface temperature of 50℃, an accelerating frequency of 300kHz, an over-voltage by 20% of the initial driving voltage ($(V_f+V_s)/2$), and a working-gas pressure of 400Torr.

(2) The lifetime is increased with an MgO thickness of 2000Å to 8000Å but is saturated over 5000Å (up to 9000Å).

(3) The AC PDP lifetime is inversely proportional to the MgO deposition rate. If the MgO deposition rate is increased, the lifetime of AC PDP is decreased.

(4) The more Xe partial pressure increases, the more the AC PDP lifetime increases.

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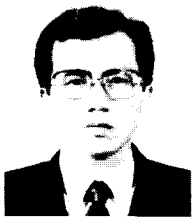

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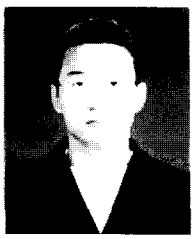

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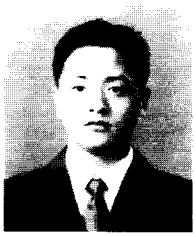

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