Effects of MgO Thin Film Thickness and Deposition Rate on the Relative Life Time of ac PDP

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Abstract

For ac Plasma Display Panel (PDP), the lifetime should be guaranteed over 30000 hours. The lifetime is correlated with the deterioration characteristics for the weakest element in ac PDP. In this paper, in order to improve the lifetime of ac PDP, a short-term relative lifetime test method for a given element in the ac PDP is proposed. By this method, the effects of MgO thin film thickness and deposition rate on the relative lifetime of ac PDP are investigated. The relative lifetime is increased with MgO thin film thickness but it was almost saturated over 5000□. The relative lifetime decreased with increase in the MgO deposition rate and increased with Xe% in the working gas of He+Ne+Xe..

1. Introduction

The ac plasma display panel (ac PDP) is a flat panel display which utilizes gas discharge. Fig. 1 shows the principal structure of a discharge cell in ac PDP. The size of a discharge cell is about 0.3mm X 1mm X 0.15mm (height). The tri-primary colors (RGB) are obtained from RGB phosphors excited by vacuum ultraviolet photons emitted from gas discharge [1, 2]. The ac PDP is now being one of the most leading candidates for the large area wall-hanging TVs [3].

The display discharge electrodes in ac PDP are coated with a lead-rich glass dielectric layer, and then transparent MgO thin films are deposited on the layer. It is well known that the performance of the ac PDP is influenced strongly by the surface glow-discharge characteristics on the MgO thin films [4-5]. The MgO thin films act, practically, as discharge electrodes.

The main role of the MgO thin films in ac PDP is to protect the dielectric layer from sputtering by ion bombardment in the glow discharge plasma. Without the MgO thin films, the discharge-inception voltage of ac PDP increases with time by ions bombarding on the dielectric layer, which causes the PbO component of the dielectrics to decompose. An additional important role of the MgO thin films is to lower the discharge voltage, which leads to low cost of the PDP[6-7]. This may be due to the fact that the MgO has the highest second electron-emission coefficient of the many candidates for the protecting materials such as CeO_2, La_2O_3, MgO and ZrO_2 [8-9]. Currently, the MgO-thin films are fabricated by the electron-beam evaporation method [10-11].

The lifetime of ac PDP is correlated with the many factors as shown in Table 1. Generally speaking, the weakest point determines the life time of ac PDP. In order to improve the lifetime of ac PDP, the weak point should be improved. However, it is difficult to find out or improve the weak points, because the lifetime is too long to test experimentally.

In this paper an accelerated relative life-time test method of MgO thin film is suggested and the relative lifetime of MgO thin film by this method is tested as a parameter of deposition rate and the thickness of the MgO, because the MgO thin film is generally well known as the weakest point in ac PDP.

2. Some main factors affecting the accelerated lifetime test of MgO thin film.

The erosion of MgO thin film in ac PDP comes from the sputtering phenomena on the MgO thin film by ion bombardment in discharge space[12-13]. The sputtering rate R may be expressed as follows from the experimental results.

$$R = k(\frac{JT}{P})^{\alpha} \cdot f \quad \text{------------------------------------} \quad (1)$$

Where, k and α : const , J : discharge current density, T : surface or ambient temperature , P : gas pressure, and f : applied voltage frequency.

2.1 Surface temperature of the panel, T.

As the surface temperature of ac PDP increases, the space charge particle and wall charges are activated and make self-erasing phenomena in the main discharge process as shown in Fig. 2. Therefore, the surface temperature rise should be suppressed not to make the self electrical discharge.

In accelerated lifetime test, the temperature of discharge cells are controlled in order not to increase the panel surface temperature above 50□, which is ordinary panel temperature in real PDP.

2.2 The working gas pressure, P.

The bombarding ion energy W is correlated with gas pressure as follows.

$$W = k(\frac{qE}{P}) \quad \text{--} \quad (2)$$

where, k : const, q : ion charge, E : electric field, and P : gas pressure.

From equation (2), bombarding ion energy increases with decrease in the pressure. In this test, the gas pressure is maintained at 400Torr in order to make almost the same glow plasma conditions with real panel.

2.3 The applied voltage and frequency

Fig. 3 shows the discharge voltage as a parameter of panel temperature. Under constant pulse frequency of 50KHz. The discharge voltage is maintained almost constant values up to 50

Fig. 4 shows the relationships between the self-discharge voltage and panel temperature when the sustain frequency is 300KHz. The self-discharge voltage increases with decrease in ambient temperature. To accelerate the erosion of the MgO thin film, the voltage 20% higher than the normal firing voltage of the panel was applied during the test period. The accelerating test point is shown in Fig. 4 whose test point is 20V lower than the self-erasing region. The accelerating test frequency 300KHz is determined by the limit of surface temperature on the panel since the panel surface temperature increases with the applied voltage frequency.

3. Experimental

Table 2 shows the specification of the 4-inch model test panel. The test panel is annealed at 300 for 2 hours in high vacuum before sealing process. The firing/sustain voltage of the panel is about 180V/140V. The lifetime test is ended when the luminance of the sample decreases about 50% of the original level. According to our experimental results, the 10% increased point of sustain voltage agrees well with the point which the luminance of the panel decreases to the half of the original level.

Although the acceleration tests are done with acceleration test conditions, such as sustain voltage 210V with 300kHz at 50□ panel temperature, the luminance and sustain voltage are tested at normal condition, that is 160V with 50kHz at room temperature. The MgO thin film is prepared by the electron-beam evaporation method .

4 Experimental Results and Discussion

Figs 5 and 6 show typical accelerated lifetime of ac PDP with MgO thickness of 2000□ and 8000□, respectively. In this case the deposition rate of MgO thin film was the same as 200±10 Å/min.

In these figures, the operating voltage Vo can be determined as a parameter of the discharge inception voltage Vf and discharge sustain voltage Vs as shown in eq. (3).

$$V_0 = \frac{1}{2}(Vf + Vs) \quad \text{------------------------------------} \quad (3)$$

From these figures, it can be noticed that the luminance of ac PDP decreases with the accelerated test time because of the MgO thin film erosion by ion sputtering and the sputtered MgO particles diffusion in the discharge space.

In case of the ac PDP with MgO thickness of 2000□ of Fig. 5 the operating voltage Vo reached 174V after 25hours. The luminance at this point was 377 cd/m^2. This value corresponds to about 50% level of the luminance of the fresh panel. If we define the lifetime of the panel as the time when the luminance decreases to half of the original value, it can be said that the lifetime of this sample is about 25 hours under the condition of accelerated lifetime test.

In case of the sample having MgO thickness of 8000□ of Fig. 6, it takes 92 hours to lose 50% of its original luminance.

Fig. 7 shows the relationships between MgO thickness and accelerated lifetime under constant deposition rate of 200□/min. The accelerated lifetime increased with the MgO thickness up to 5000□. Thereafter, the lifetime was saturated. Therefore, in this case the optimum thickness of MgO in ac PDP may be about 6000 ~ 7000□.

Fig. 8 shows the relationships between MgO deposition rate and accelerated lifetime under constant MgO thickness of 5000□. The results show that the accelerated life time of ac PDP decreased with the MgO deposition rate. The higher deposition rate the lower the accelerated life time. The reason may be due to the structural difference by the difference of the deposition rate, that is, high degree of crystallinity and fine structure in obtained under lower deposition rate.[14-15]

Fig. 9 shows the relationships between Xe% in the working gas of He+Ne(30%)+Xe and the accelerated life time of ac PDP under constant MgO thickness of 5000□ and deposition rate of 200□/min. The accelerated life- time increased with Xe%. The reason why the life time increase with Xe% may be due to,

(1) the sputtering rate for Xe ion is much lower than Ne ion.
(2) Xe gas suppresses the MgO sputtering by Ne ion, just like as Ar in light bulb.

Therefore, the lifetime is also connected with the rate of Xe/Ne in the working gas of ac PDP.

Fig. 10 shows the electrode structure of ac PDP and the SEM photo of MgO surface after accelerating lifetime test. The erosion of MgO in the glow discharge in ac PDP is occurred by ion bombardment from the glow discharge plasma on the MgO thin film. The maximum erosion point was B point of the Fig. 10(a), because the discharge initiated from the edge of the ITO electrodes. From Fig. 10(c) and (d), the amorphous MgO is eroded at first and the crystalline part is remained. Therefore, high degree of crystallinity can elongated the life time of ac PDP.

5 Conclusion

In this paper, a short-term relative lifetime test condition for a given element in ac PDP is proposed. By this method, the effects of MgO thin film thickness, deposition rate, and Xe% in the working gas of He+Ne+Xe on the relative lifetime of ac PDP are investigated. The relative lifetime increased with the MgO thickness up to 5000Å. Thereafter, the lifetime is saturated. Therefore, the optimum thickness of MgO thin film in ac PDP assumed to be 6000 ~ 7000Å.

The relative lifetime of ac PDP decreased with the MgO thin film deposition rate which can be noticed from the structural variation of MgO thin film. The degree of crystallinity is also one of the important factors in the lifetime of ac PDP. The relative lifetime increased with Xe% in the working gas of He+Ne+Xe, since the erosion rate connected directly with the rate of Xe/Ne.

7. References

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Table1. Principal Factors for the lifetime of ac PDP.

Factor	Parameters
MgO	1) Deposition process (e-beam, sputtering, ion plating)
	2) The 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 manufacturing 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

Table 2. Specification of the test panel.

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

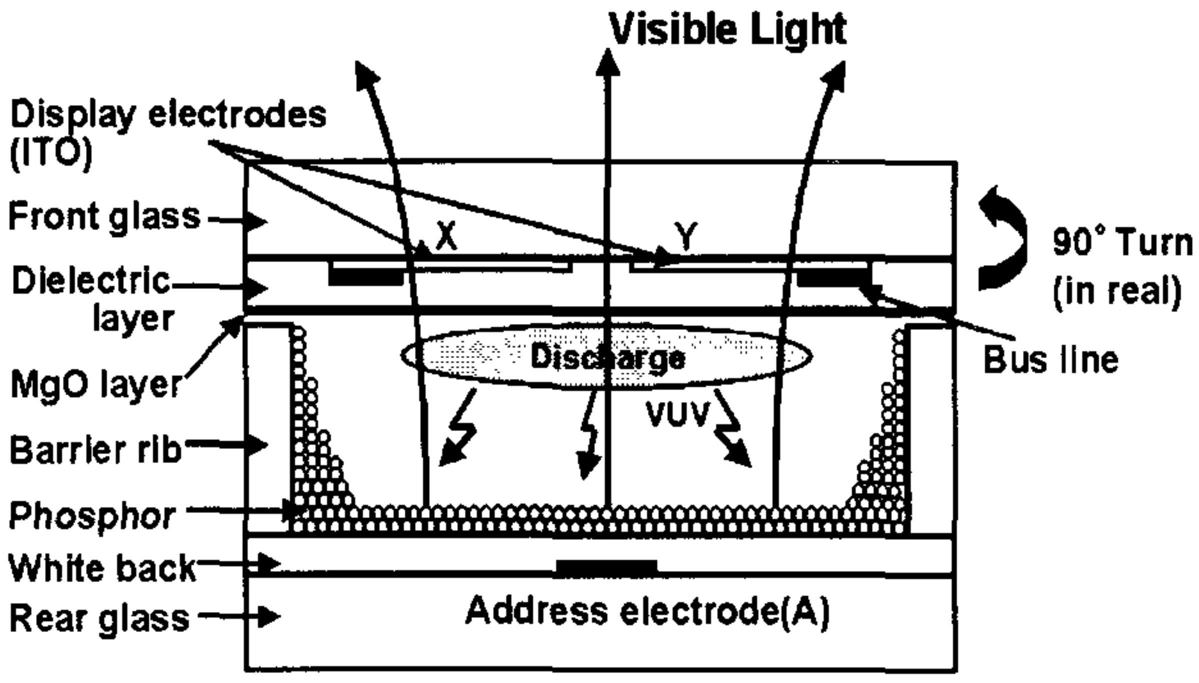

Fig. 1 Principle structure of a discharge cell in ac PDP.

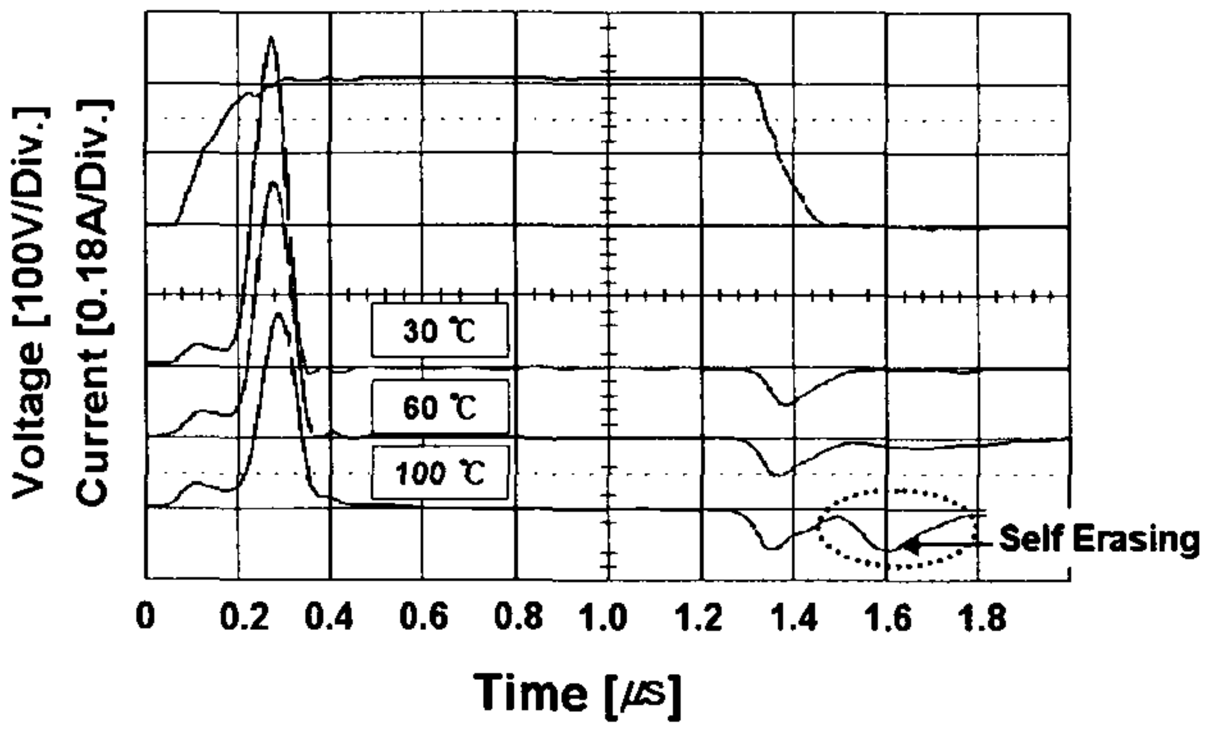

Fig. 2 The current waveform according to ambient temperature.

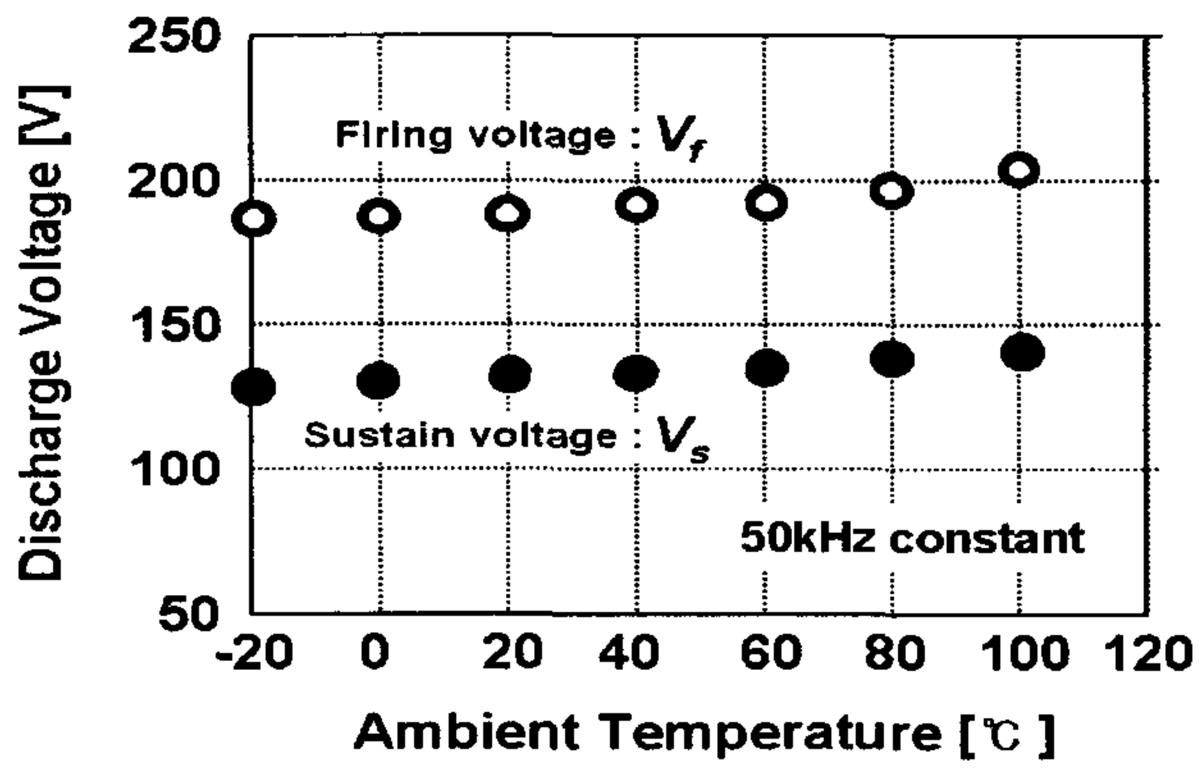

Fig. 3 The characteristic of discharge voltage as a parameter of an ambient temperature at 50kHz.

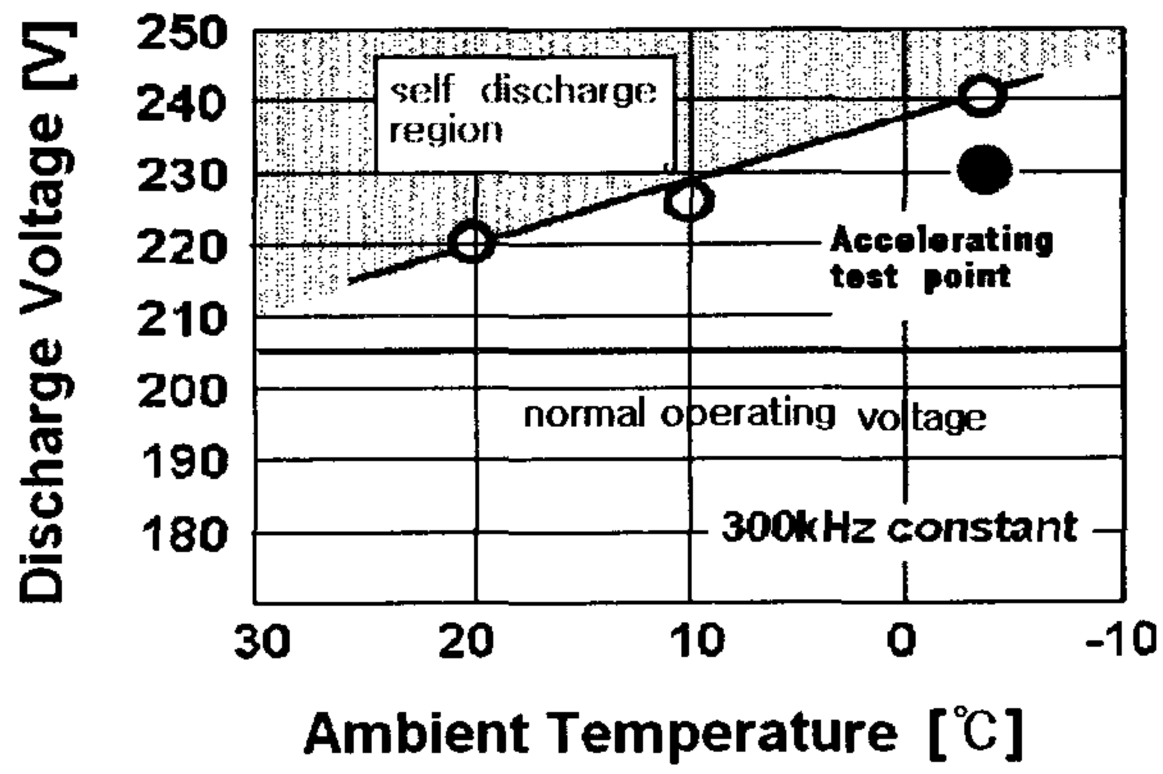

Fig. 4 The self-erasing region at 300kHz and the operating temperature.

(Vf ; 235V, Vs ; 165V at 50kHz, working-gas ; He +Ne(30%) + Xe(4%), VGA class)

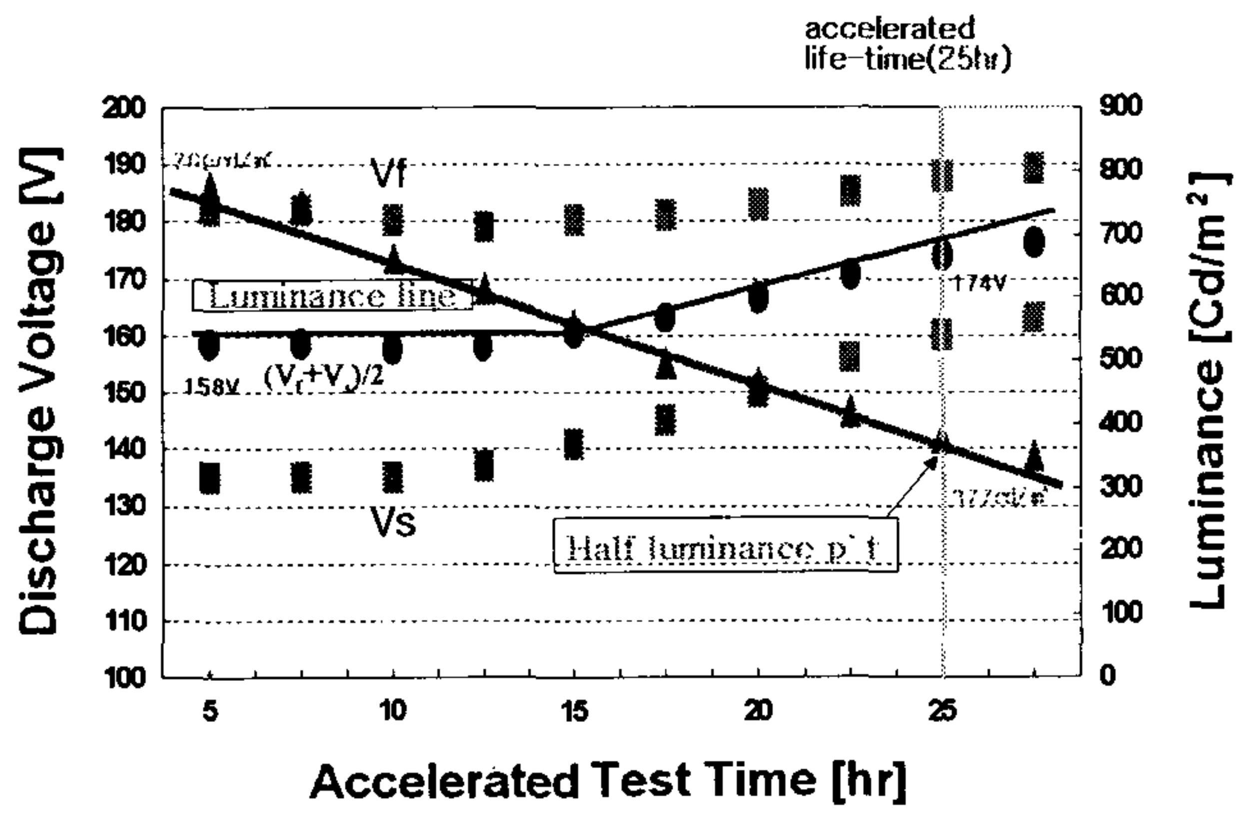

Fig. 5 A typical accelerated lifetime for MgO thickness of 2000□ with deposition rate of 200□/min.

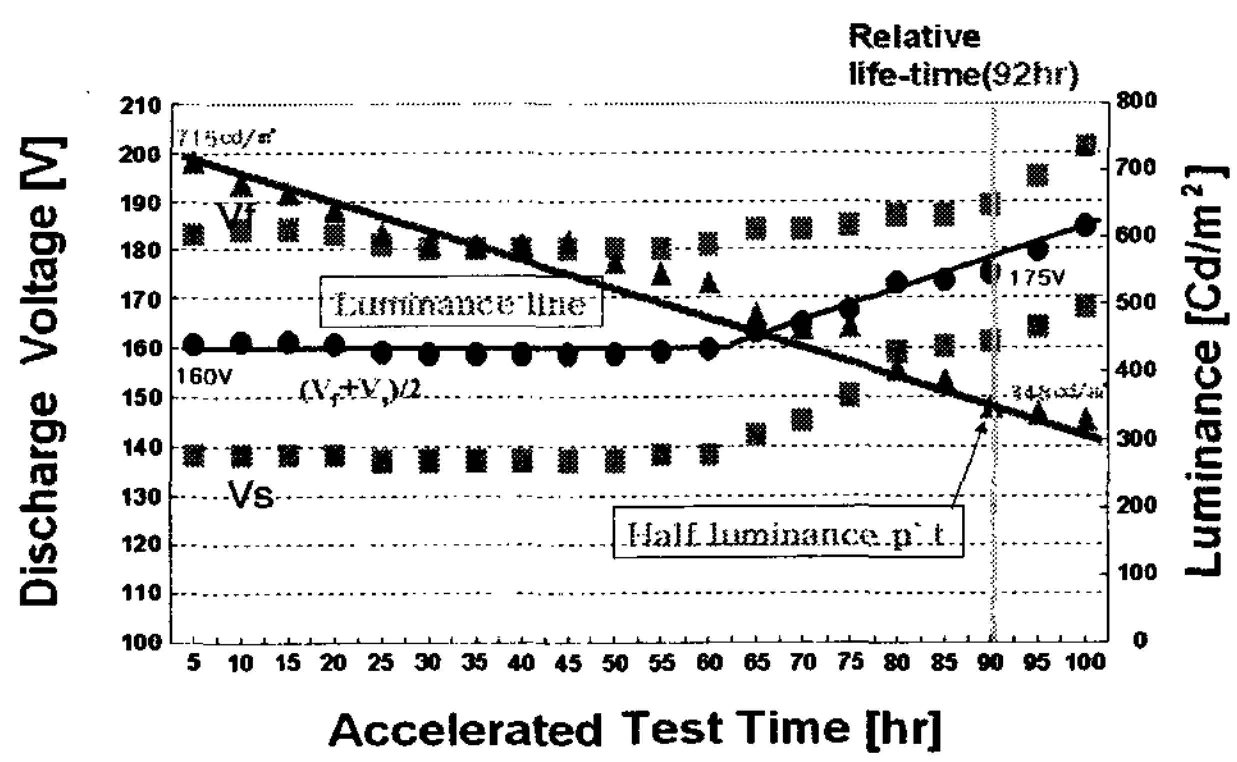

Fig. 6 A typical accelerated lifetime for MgO thickness of 8000□ with deposition rate of 200□/min.

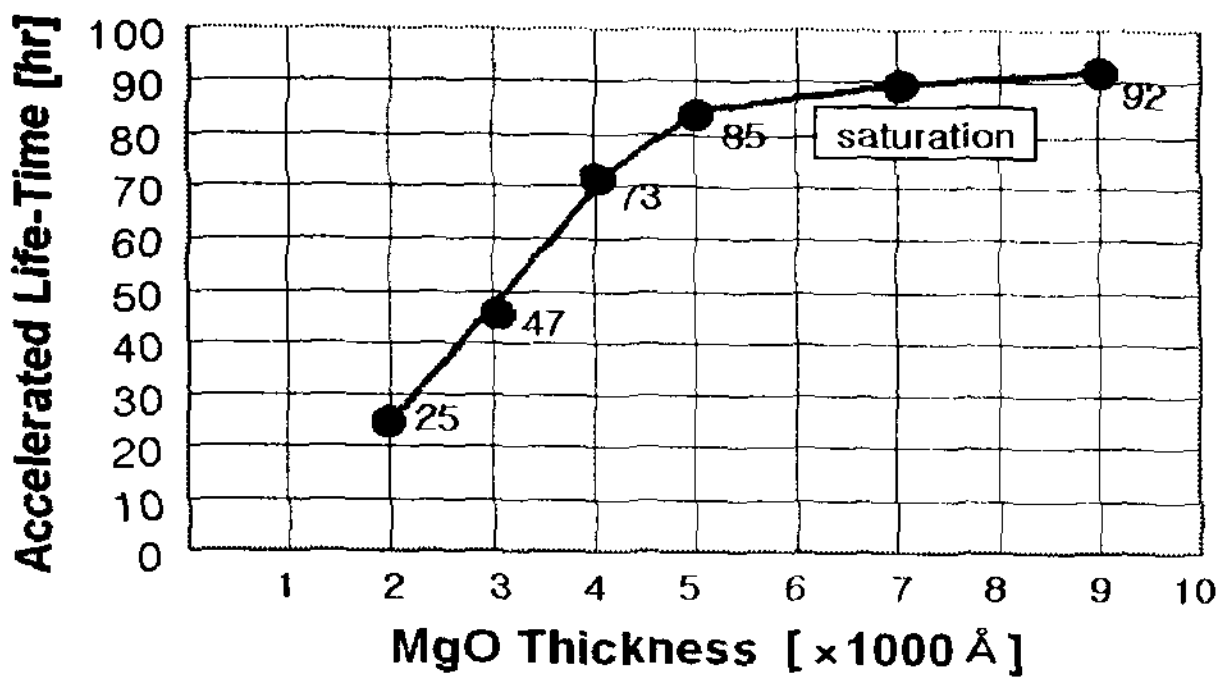

Fig. 7 The relationships between MgO thickness and accelerated lifetime of ac PDP under constant deposition rate of 200□/min.

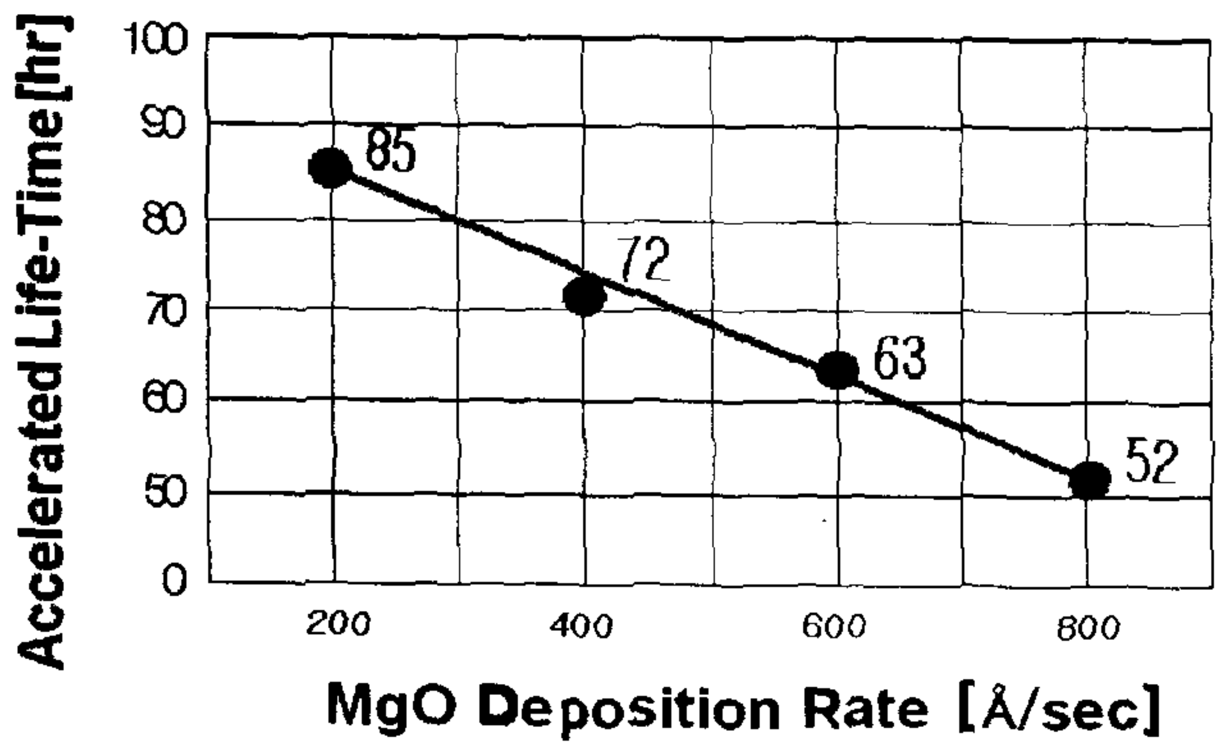

Fig 8. The relationships between and accelerated lifetime of ac PDP under constant MgO thickness of 5000□.

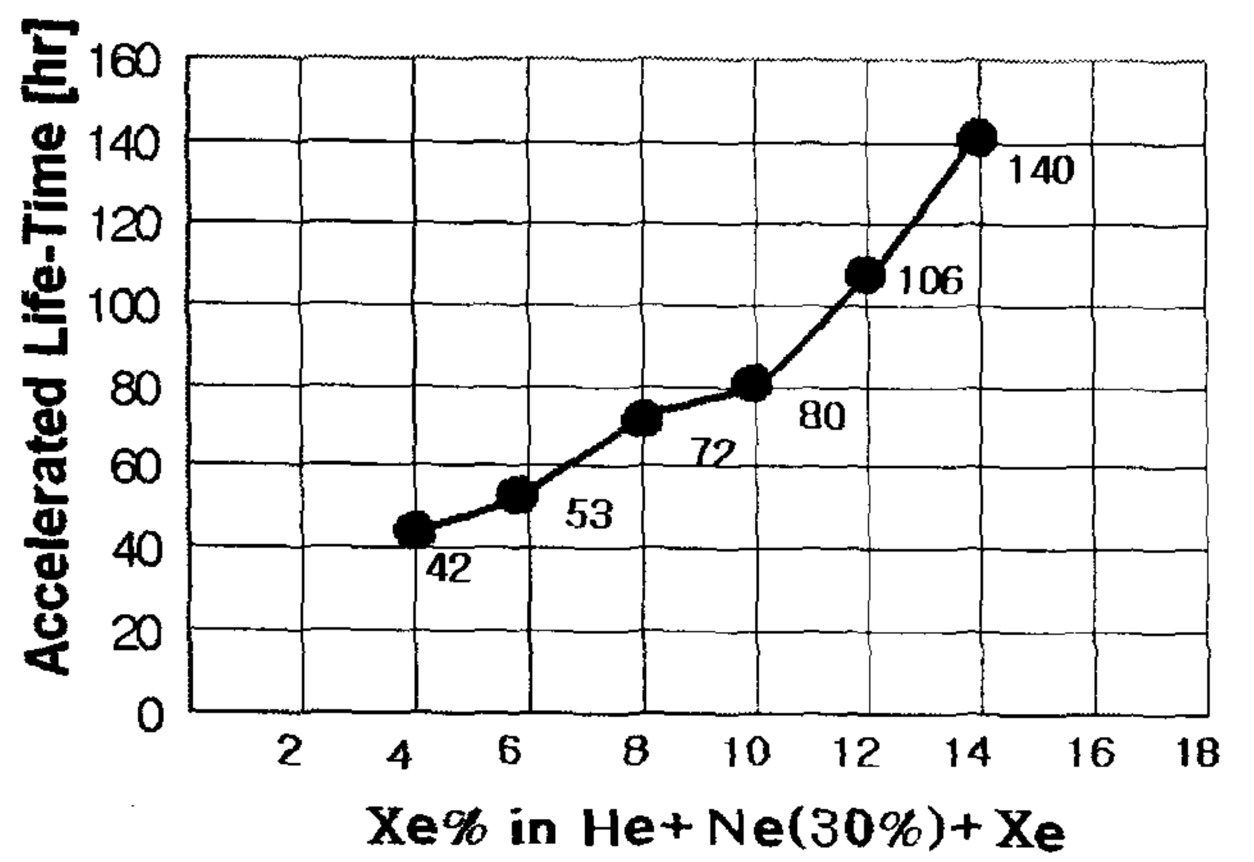

Fig. 9 The relationships between Xe% in the working gas of He + Ne(30%) + Xe and the accelerated lifetime of ac PDP.

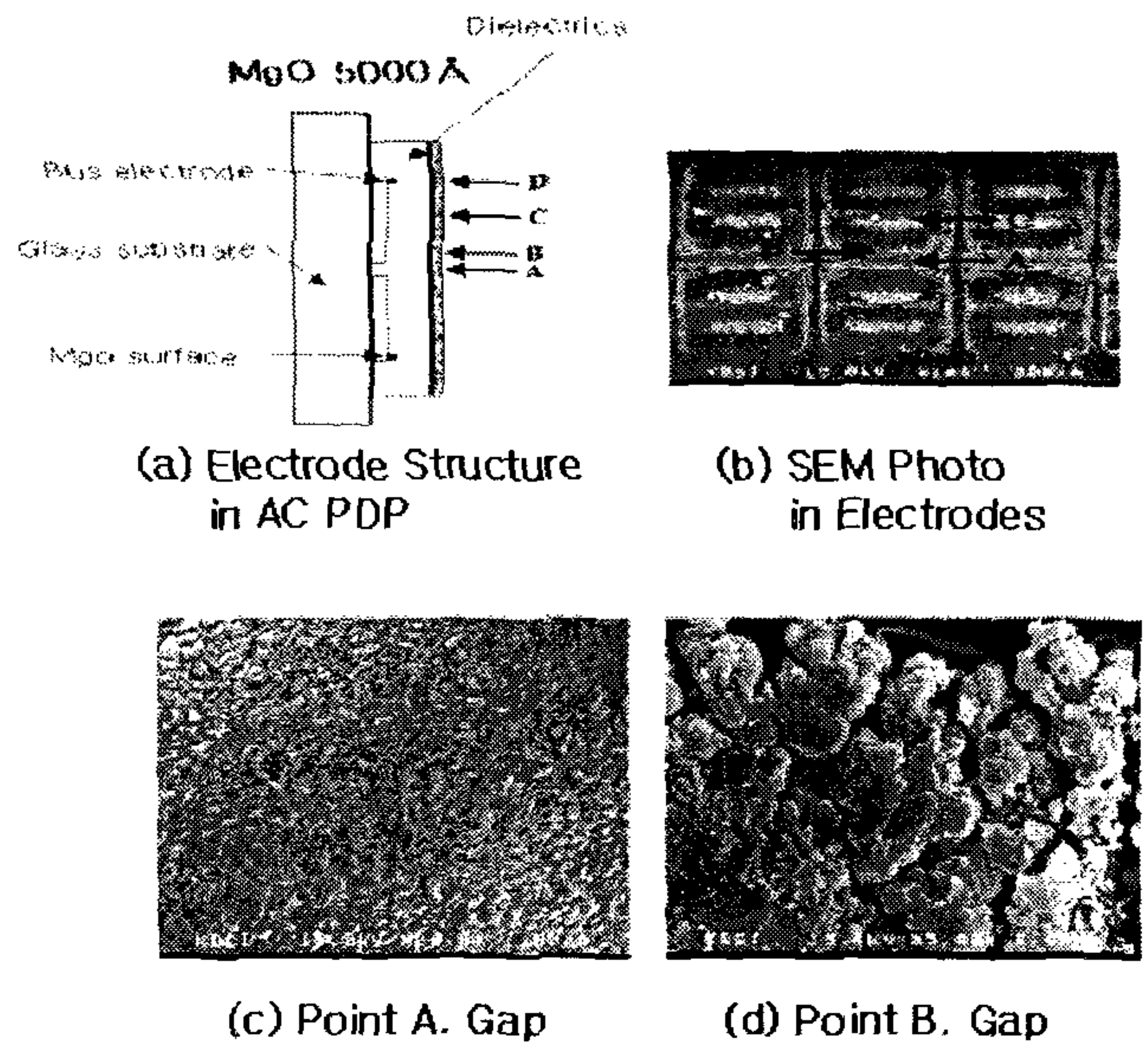

Fig. 10 Electrode structure and SEM photo of MgO surface after accelerated lifetime test.