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Vacuum Packaging Technology of AC-PDP using Direct-Joint Method

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Abstract

We suggested new PDP packaging technology using the direct joint method, which does not need an exhausting hole and tube. The advantages of this method are simple process, short process time and time panel package. To packaging, we drew the seal line of glass frit by dispenser followed by forming the lump, which provide pumping-out path during the packaging process. And, we have performed a pretreatment of glass frit to reduce the out-gases. After which, both front and rear glass plates were aligned and loaded into vacuum packaging chamber. The 4-inch monochrome AC-PDP was successfully packaged and fully emitted with brightness of 1000 cd/m^2. Also, glass frit properties for pretreatment condition was investigated by AES and SEM analyses.

Keywords : packaging, direct joint method, PDP, lumps

1. Introduction

Plasma display panel(PDP) is one of the most promising flat panel displays(FPDs). The advantages of PDP devices are well known; simple structure, high resolution, fast response time, large screen and wide view angle[1,2]. A PDP panel is normally operated at gaseous ambient to generate the VUV(Vacuum Ultra Violet) ray from xenon in the penning mixture gas[3]. However, a packaging technology is very important because of protection of the devices from the surrounding effect related to lifetime and durability. In general, PDP have been packaged by the cathode ray tube(CRT)-like method that is proven to be limited in terms of the out-gassing, metal oxidation by high temperature process, difficult handling, and the lower vacuum conductance due to small inner volume[4,5]. Also, PDP packaging carried out by cart type packaging equipment, of which problems include difficult tube alignment between panel and system, easy cracking of the tube, unstable gas uniformity, and requirement of 2nd tip-off process due to the length of tube. Also, residual gases such as CO and CO_2 cause an increase in the firing or sustain voltage. So, the tubeless packaging method by electrostatic bonding was introduced last year. Using this method it is possible to solve the previously mentioned problem, but, it needs an amorphous silicon film deposited support glass to package[6].

This paper reports a new PDP packaging technology using direct joint method, which does not need exhausting tube and hole. The surface contamination through the by glass frit for a sintering condition was investigated through the by AES analyses. Long-term reliability of packaged PDP was evaluated by both light

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emitting and driving voltage variation test. We packaged 4-inch monochrome AC-PDP with 6 mm thickness by the previously mentioned process. This method would be possible to attain advantages such as simple, short time, low cost process, improved gases uniformity by high vacuum efficiency and thin panel fabrication because of removing of the exhausting hole and tube.

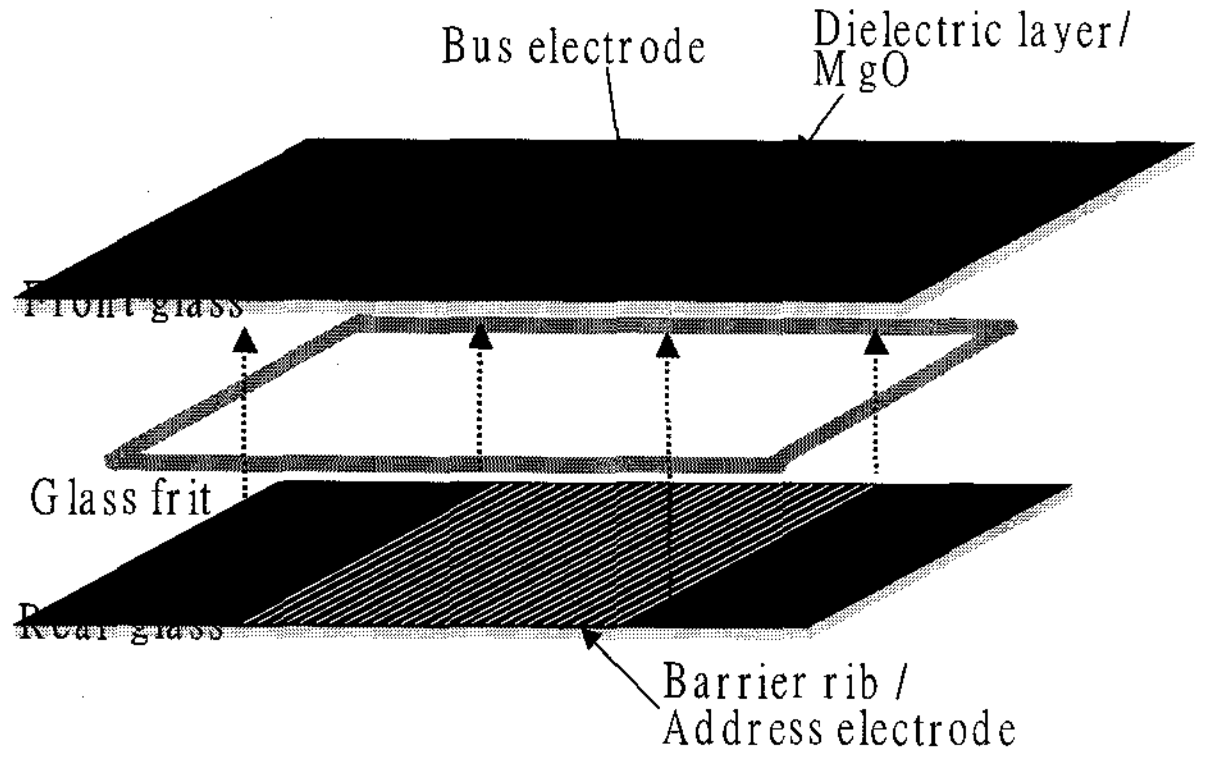


Fig. 1. Schematic diagram of direct joint packaging method.

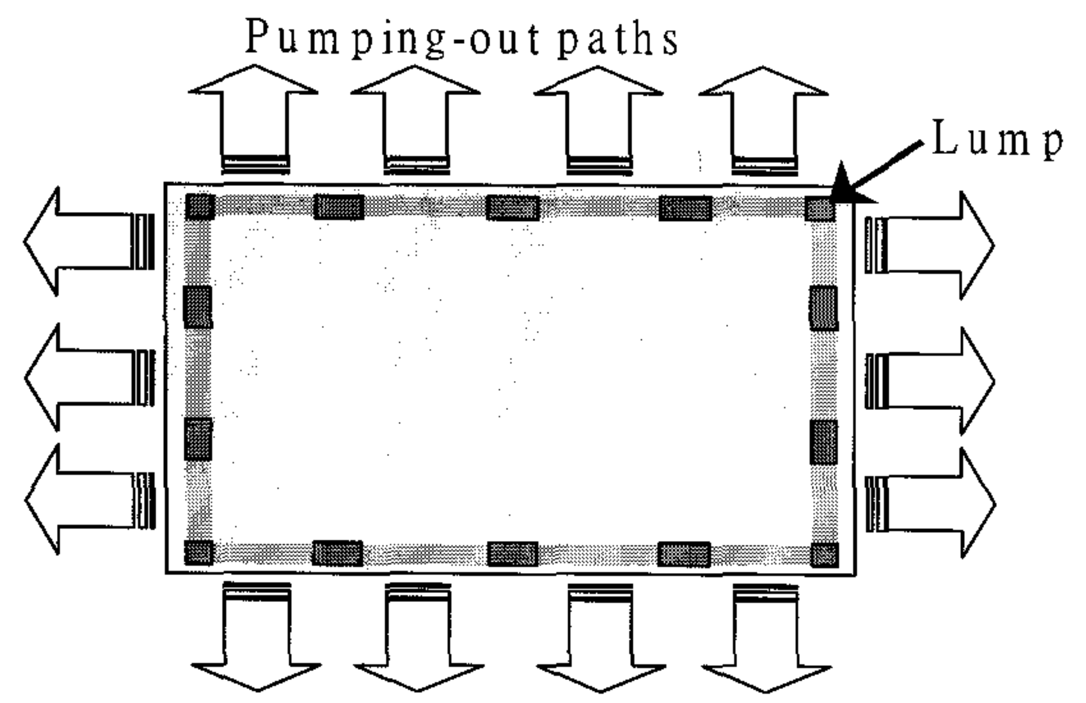


Fig. 2. Schematic diagram of lumps and pumping-out paths.

2. Experimental

A surface discharge AC-PDP with three electrodes system is widely used, in which X and Y electrodes covered with dielectric layer are parallel to each other in the front glass. An MgO protective layer is deposited on the dielectric layer by the electron beam evaporation with thickness of 0.5 μm. On the rear glass the address electrode and barrier rib are perpendicular to the two sustaining electrodes. Fig. 1 shows the schematic diagram of proposed structure by direct joint method. In this method, we used only glass frit without exhausting hole and tube. The seal line of glass frit was drawn on rear glass with green phosphor by dispenser followed by forming a lump, which provide a pumping-out path. Fig. 2 shows the schematic diagram of a lump and pumping-out path. The pumping-out path dimension between a lump and a lump was related to pumping efficiency from inner to outer panel. The glass frit was sintered in N_2 ambient at a temperature of 380 °C and the front plate was put on the rear plates. The panel was input on the vacuum chamber followed by pumping-out to 1×10^{-6} torr with temperature of 250 °C. The Xe(3 %)-He(27 %)-He gases were then filled to about 400 Torr. And, the panel was heated up to 350 °C to melt the glass frit using a halogen lamp. The melting point of glass frit in vacuum environment is the lower than atmosphere. The 4-inch PDP was successfully packaged with about 360torr in room temperature.

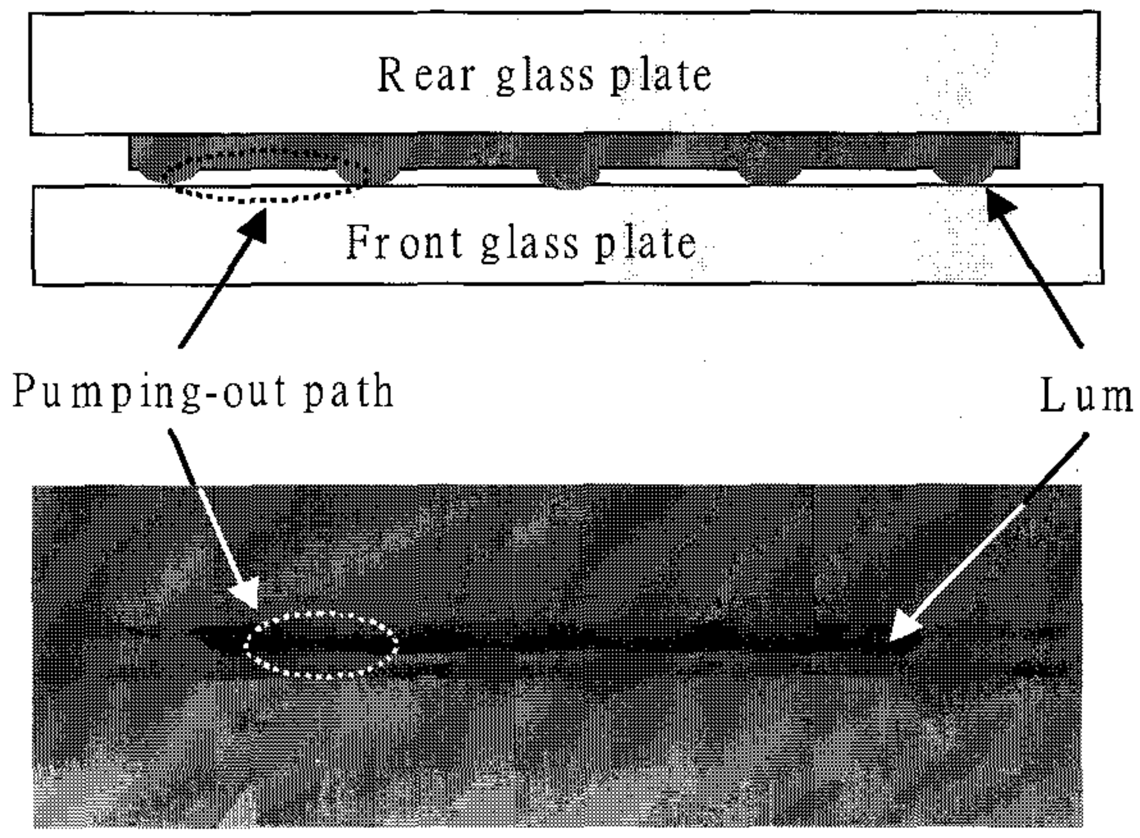


Fig. 3. Cross sectional diagram and optical view of the lump formation.

3. Results and Discussion

Fig. 3 shows the cross sectional diagram and photograph of lumps formed on seal-line, respectively. The distance between lump provide a pumping-out path from inner to outer panel. We can show the pumping-out path in the image. This structure has a high vacuum efficiency because of the many pumping-out paths in all sides of the panel. The rear glass plate was aligned on the front glass. The pumping-out path dimension between a lump and a lump was related to pumping efficiency. The vacuum efficiency was calculated by theoretical concepts such as conductance, which is the ability of pipe to allow a unit volume of gas to pass through at a time[5,7]. We have calculated theoretically the conductance of pumping-out path. Then, conductance [C] of rectangular shape for one path becomes

$$C=31.1\frac{L^2H^2}{(L+H)W}\ [\ell/\sec] \qquad (1)$$

where, L is distance of lumps, H is lump height and W represent the seal-line width.

Table 1. Theoretical conductance values as function of path size and seal line length.

Length [μm]		Conductance for seal line[ℓ/sec]		
Path	Lump	1cm	20cm	40cm
100	900	0.0018	0.036	0.072
300	700	0.0059	0.118	0.236
500	500	0.01	0.2	0.4
700	300	0.014	0.27	0.56
900	100	0.0182	0.364	0.728

The conductance values as a function of path sizes and the seal line lengths were calculated and summarized in Table 1. In this paper, we formed a pumping-out path of 700 μm distance and lump of 300 μm length per 1 cm with 150 μm height. Then a seal-line width was 3 mm. The calculated conductance was 0.0139 ℓ/sec per seal line of 1cm, which is similar to a conductance of exhausting tube having 2 mm-diameter and 4 cm-length. Therefore, we could obtain the linear increased conductance through increase in the PDP size due to the many paths of seal line length. Based on the theoretical calculation, we obtained the total conductance of 0.41 ℓ/sec in our panel with a seal-line length of 29 cm. Also, the partial vacuum level in panel would be improved because a pumping-out path exists at all sides of the panel. Since the conductance increased linearly by increasing the panel size, it is able overcome the limitation of pumping-out problem as against conventional method.

To package using the direct joint method, the sintering process of glass frit is very important. The glass frit is composed mainly of PbO, SiO_2 and organic binder. If we do not perform a burn-out process or under critical temperature process, the device surface is contaminated by Pb, C and O. In order to investigate the above problem, we carried out the auger electron spectroscopy (AES) analysis. We prepared two panels. One was performed burn-out process of glass frit at 380 °C. The other is not performed burn-out process. We placed the cleaned Si wafer in panel and sintered in vacuum environment. Fig. 4 shows the AES analysis results for Si wafer surface. The "No frit" sample carried out annealing in same condition without glass frit. From the results, we can show the C, O, and Pb peaks. But, the other peak is not observed under our process condition.

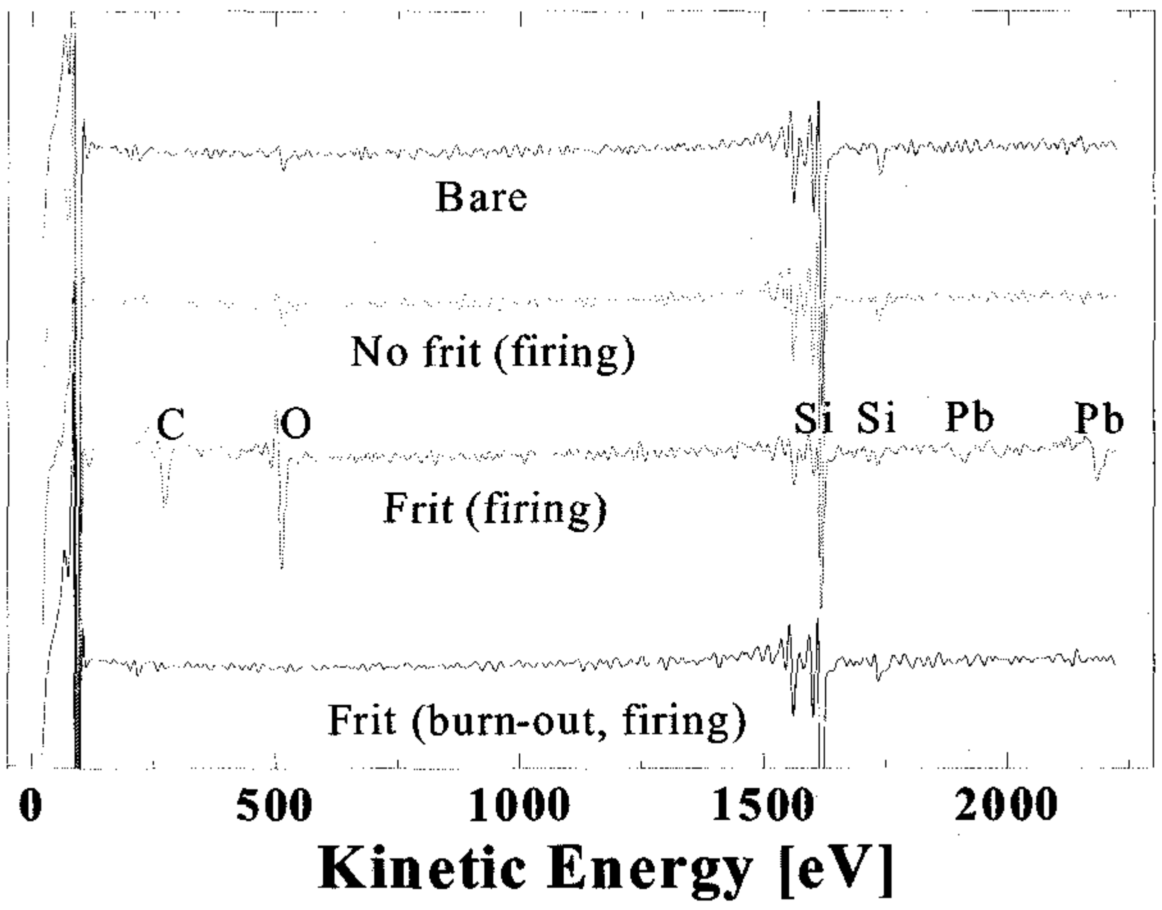


Fig. 4. *Contamination analysis on Si wafer surface by AES.*

We know that the burn-out process are very important factor on for direct joint method, and also, that the bubble in a glass frit is caused by out-gases and micro leak by gas permeation. Therefore, an optimized process is required to remove bubbles. We were successful in solving the above problem by firing process control. Fig. 5 shows the cross sectional view for sintered glass frit. The state of frit is the same with atmosphere condition. In general, the origin of bubble is ionized oxygen from PbO during high temperature process. Therefore, process temperature control is very important in atmosphere or vacuum ambient. However, the 4-inch AC-PDP was successfully packaged. Fig. 6 shows the full green light emission image for front and backside of a packaged 4-inch AC-PDP with 6 mm thickness by direct joint method. This panel does not have a barrier rib and address electrode. Then, the luminance is about 950 ~ 1000 cd/m^2 at arbitrary spot of panel. The maximum firing voltage of 220 V with

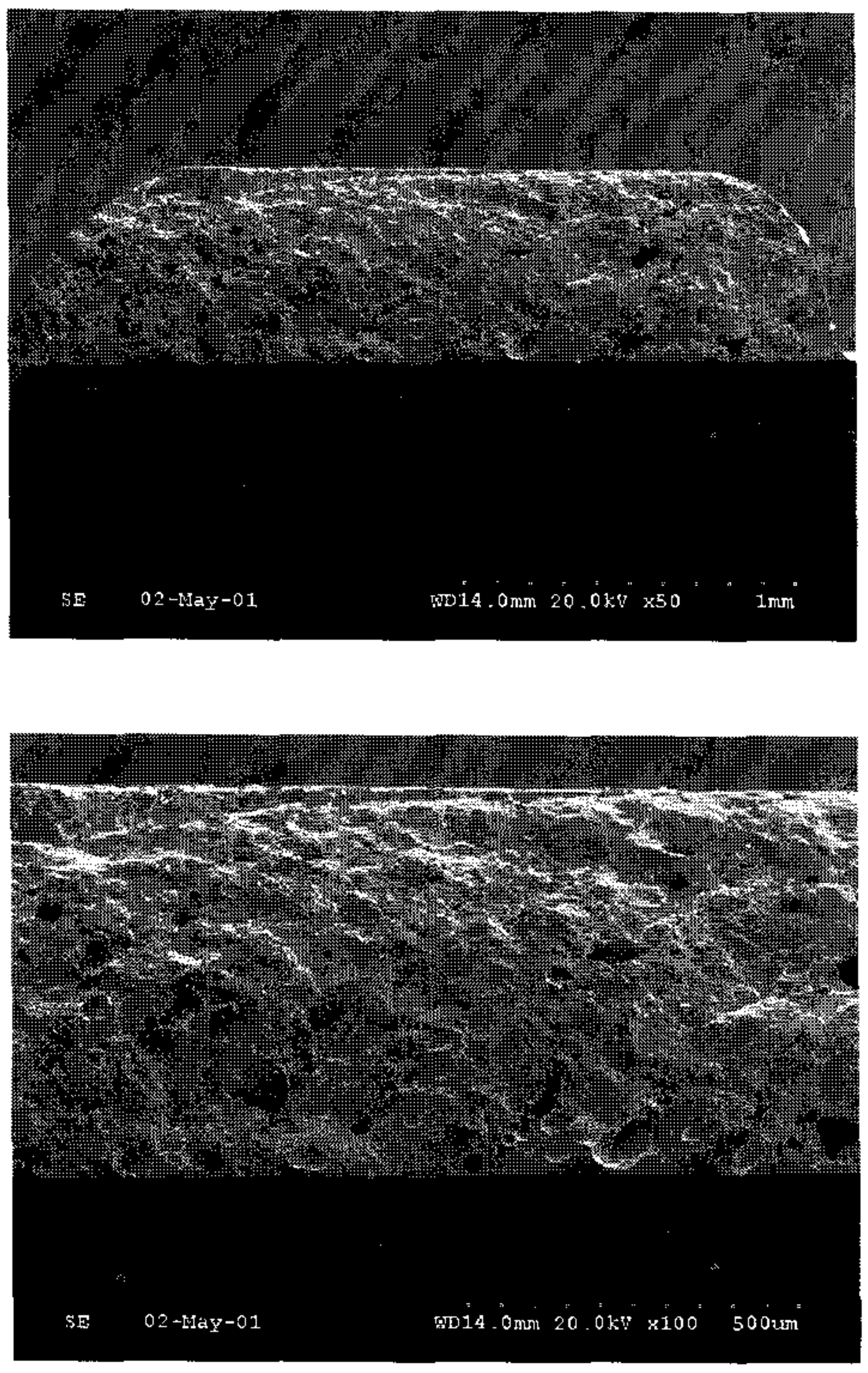
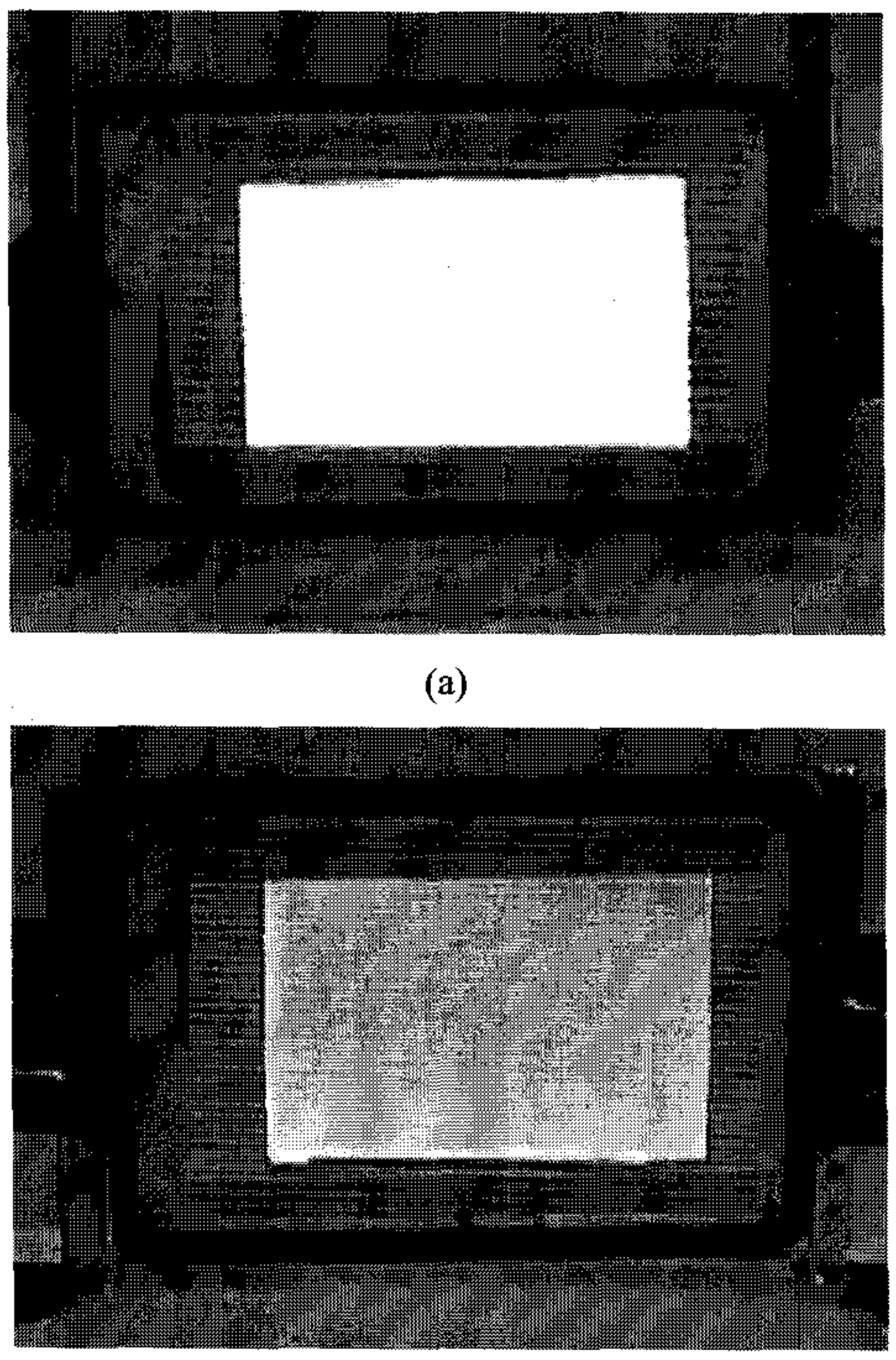


Fig. 5. Cross sectional view of glass frit sintered in vacuum environment.


(a)

(b)

Fig. 6. Green light emission from the packaged 4-inch AC PDP; (a) front and (b) backside.

50 kHz of driving frequency was applied to panel without address voltage. In order to investigate the variation of firing and sustaining voltage as a function of driving time, external bias signal was applied to panel constantly as the ON for 10 min and OFF for 30 min during 270 hours, as shown in Fig. 7. Both firing and sustaining voltage were linearly decreased for the aging time variation for 160 hours and saturated afterward. Generally the aging time test was performed on the safety operation of panel. But, our method fakes up a longer time than conventional method because of the different aging test method. From the observed results, we can propose that the direct joint method will be a good methed to be applied to PDP packaging, as it brings about a low cost, short time process, high vacuum efficiency, and simple packaging process.

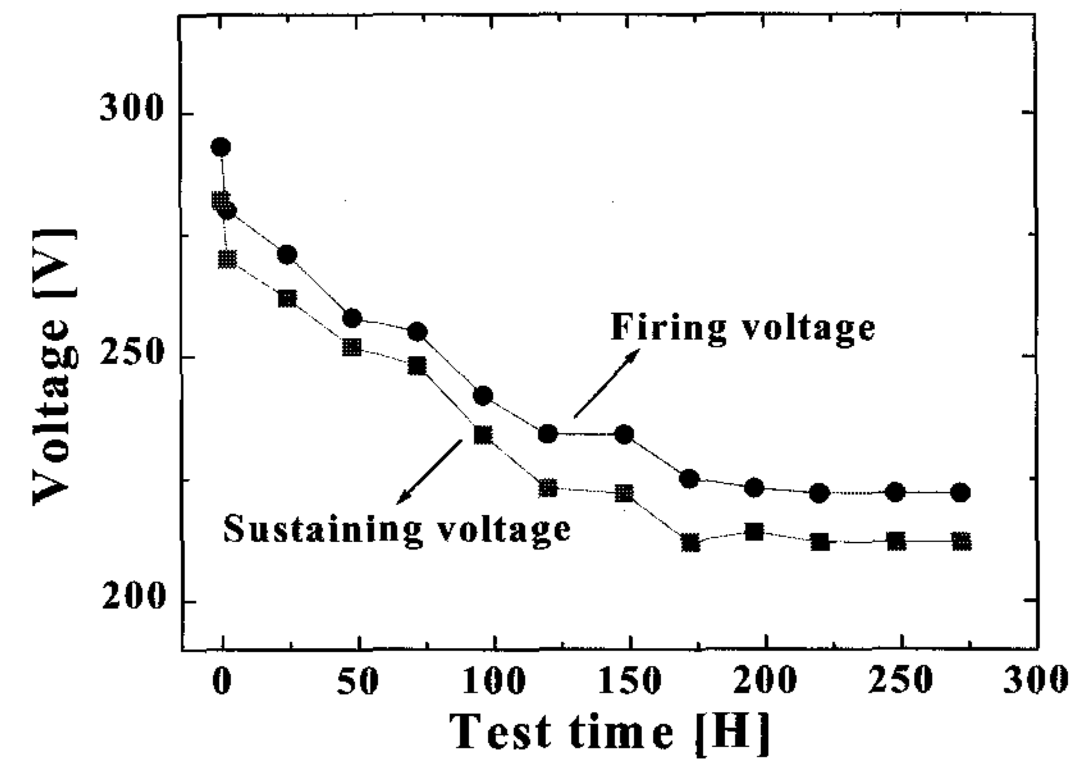


Fig. 7. Firing and sustaining voltage variation as a function of aging time.

4. Conclusion

The AC-PDP was successfully packaged and fully emitted as brightness of 1000 cd/m^2 by direct joint method. From the observed results, we can conclude that the method will bring about low cost, short time process, high vacuum efficiency, and simple packaging process. Therefore, we think that the proposed packaging methods can be applied to FED, PDP, sealing of sensors, automotive and avionics industries, high performance back-lights for liquid crystal displays, etc.

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