Characterization of PDP Performance Prepared by Vacuum In-line Sealing Technology

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Abstract

By using vacuum in-line driving and photoluminescence measuring system, we have examined the electrical and optical characteristics of plasma display panel produced by vacuum in-line sealing technology. In addition, the relationship between luminous efficiency and base vacuum level before filling discharge gas was analyzed. In the case of base vacuum level of 1.33×10^{-1} Pa, the firing voltage of a 2-inch diagonal PDP panel was ranged from 312 to 343 V depending on the discharge gas pressure of 2.667×10^{4} to 4×10^{4} Pa at room temperature, Whereas in the case of 1.33×10^{-4} Pa, the firing voltage was reduced by 40 V and luminescence was improved slightly.

Keywords : PDP, vacuum In-line sealing

1. Introduction

One of greatest achievements in large-format displays is the plasma display panel (PDP). However, for its further expansion in share of the large-sized display market, it is great importance to reduce the cost of manufacturing and improve its luminance efficiency. Among the various problems in reducing PDP fabrication cost, there is sill room for improving sealing process. A PDP composed of two glass plates are generally filled with a mixture gas such as Xe and Ne, and driven by a row-column passive-matrix method. Typically, the front glass plate is composed of ITO electrodes, bus electrodes, a dielectric layer, and a MgO layer while the rear glass plate is composed of address electrodes, reflecting layer, barrier ribs, and phosphor layers. In the conventional sealing method, the first two plates were sealed together by using frit sealing under the atmospheric environment. Then, the panel was evacuated by a diffusion pump through a glass tube sealed at the corner of the rear glass plate, of which dimension is typically a few tens of cm in length and ~2 mm in diameter. After baking for 12 hours approximately, a mixture of discharge gas was introduced into the panel and the glass tube was tipped-off. The total time required for the sealing process was longer than 15 hours and the obtained base vacuum level was limited by the pumping conductance of the panel, mainly attributed from the rectangular nozzle-shaped structure given by the barrier ribs and the closely spaced glass plates. In the PDP panel that is 40inch in diagonal size with 150 μm gap between the two glass plates and 320 μm pitch between the barrier ribs, we estimated that the base vacuum level at the panel center was less than 1.33×10^{-1} Pa[1, 3].

The most plausible method for obtaining the initial high vacuum level with minimum sealing process time is the vacuum in-line sealing technology where all

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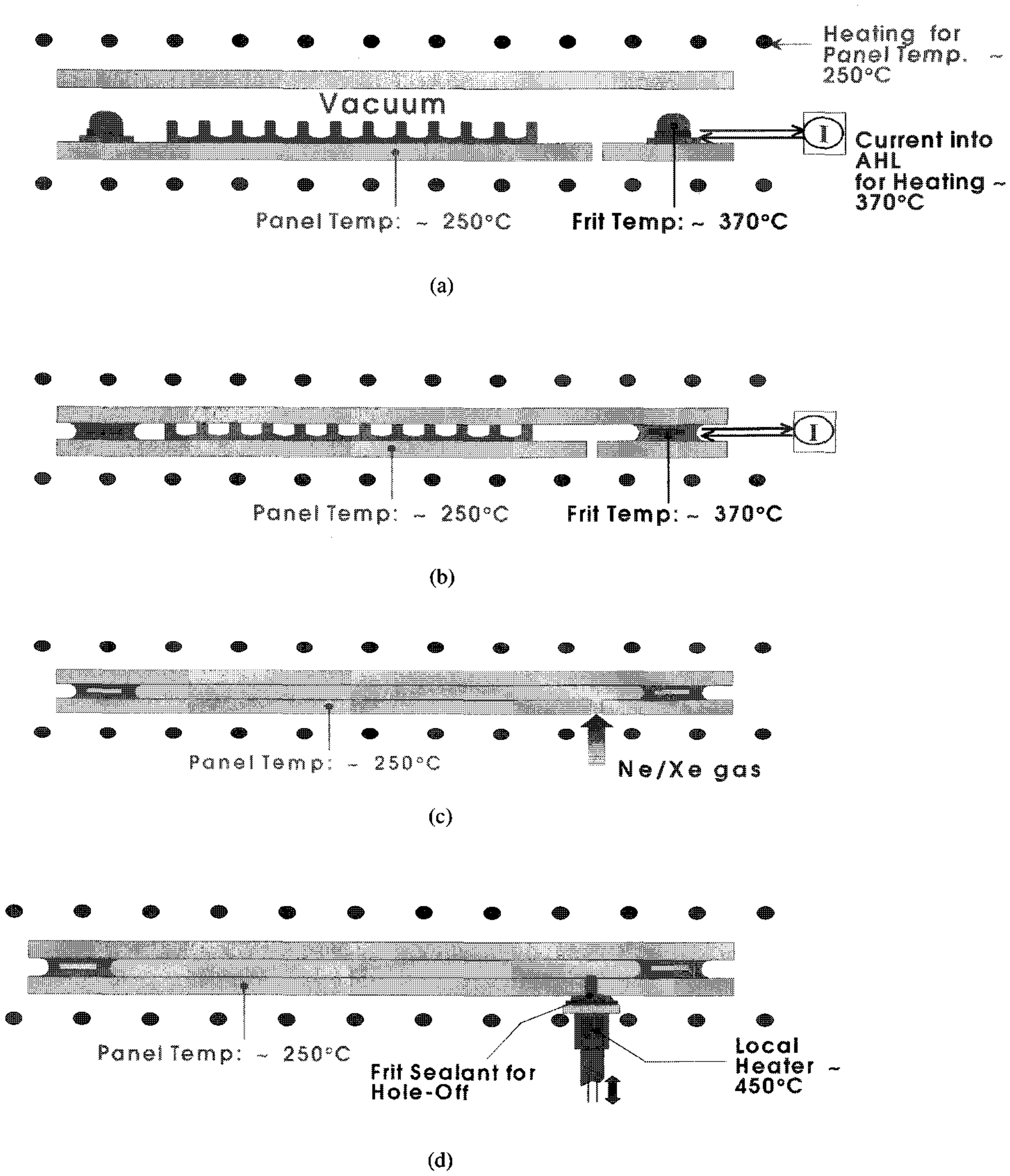

Fig. 1. Conceptional view of the vacuum in-line process sequence with an auxiliary heating line (AHL): (a) current flowing through AHL under panel heating at 250 °C, (b) sealing of two glass plates, (c) gas filling inside sealed panel, and (d) hole-off by locally melted frit sealant.

processes are performed after fabricating two glass plates in a high vacuum chamber. In the previous works[1-4], we had demonstrated the feasibility of the vacuum in-line sealing technology by showing an operational PDP fabricated by using that technology.

In this study, the dependence of the operation voltage and luminance on the base vacuum level obtained prior to gas filling was investigated for several Xe-Ne gas pressures in a stripe type cell structure. The panel was introduced into a vacuum chamber and driven by a driver circuit interfaced to the chamber via an electrical feed-through. Luminance was observed by using the in-situ measurement from the luminance colorimeter installed on the top-side view port.

2. Experimental Procedures

In our study a test panel was composed of two plates of soda-lime glass. The glass plate had a size of 6 cm × 9 cm and a thickness of 2.8 mm. The size of active area was 3.5 cm × 3.5 cm. In this study, an auxiliary heating line (AHL) was introduced inside the frit by using a screen printing of Ag paste and annealing, that is used as a part of local heating source for the frit melting in order to improve the uniformity of sealing and to reduce the processing temperature further. In fact, the PDP panel was successfully sealed at the chamber temperature of 250 °C with AHL and the base vacuum level maintained at 1.33×10^{-3} Pa and free of any leakage leak. Fig. 1 shows the conceptional view of the vacuum in-line sealing process, including the AHL. Fig. 2 describes the sealing temperature profile, including a panel temperature regulated by an ambient heating array and frit line temperature controlled by the AHL voltage. The chamber temperature was maintained at 250 °C and the voltage was increased to the AHL at the rate of 0.05 V/min. From the result, we can see that the local temperature along the heating line could be well controlled by applying the voltage without the glass breaking under a chamber temperature of 250 °C. At the voltage of 3.7 V, the local temperature on the AHL reached ~330 °C, which was an appropriate temperature for a vacuum sealing reported from the previous results [5, 6].

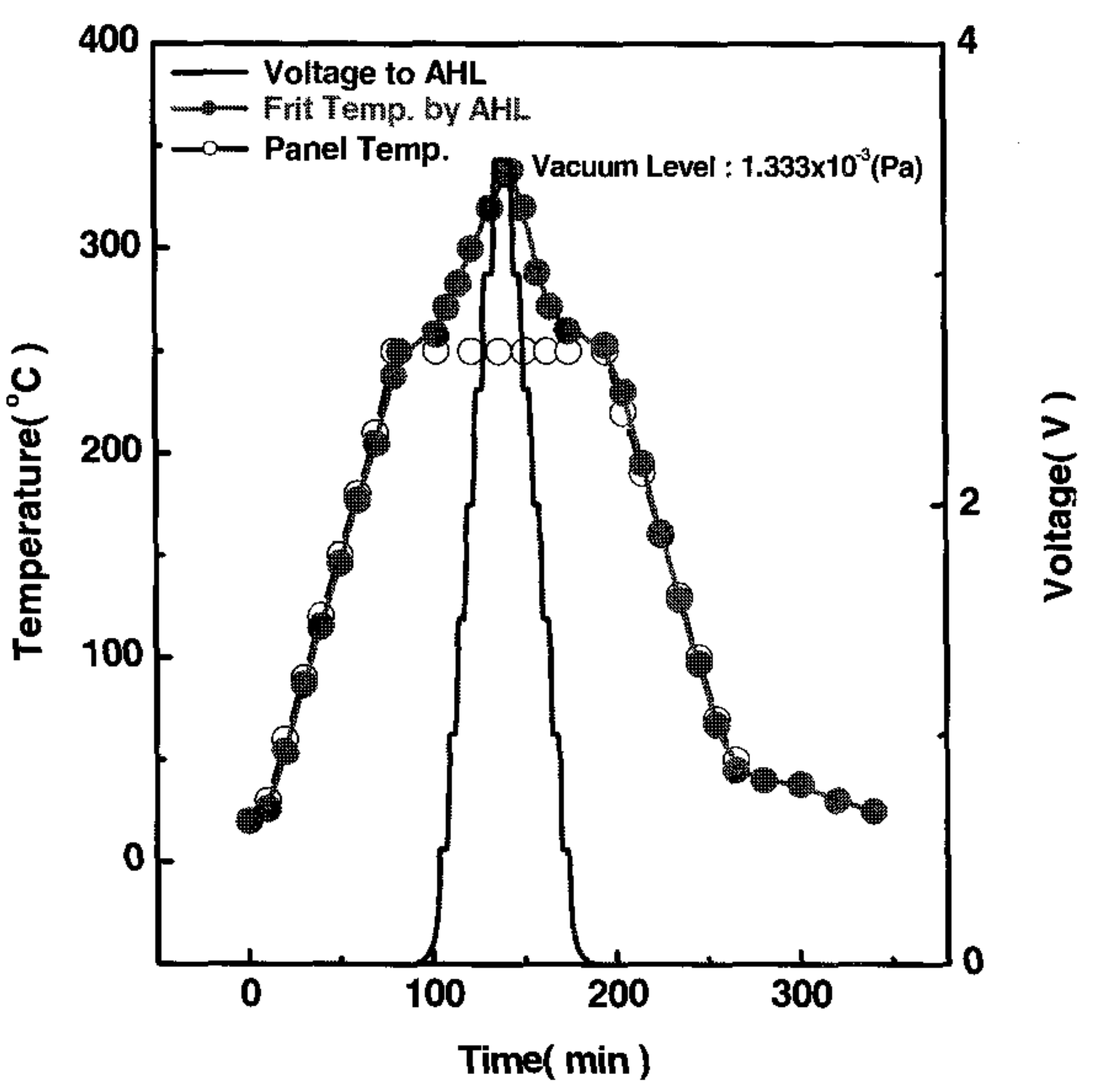

Fig. 2. Temperature profiles of glass plate by chamber heating source and sealing frit by auxiliary Ag heating line.

The tubeless-type PDP panel fabricated by using this vacuum in-line sealing technology is shown in Fig. 3. A comparison in the sealing process cycles between the conventional and the newly developed vacuum in-line method is shown in Fig. 4. As can be seen from the figure, the total sealing time and temperature cycles could be significantly reduced with the vacuum in-line sealing method.

In order to investigate the effects of base vacuum level on the electrical and optical characteristics of PDP,

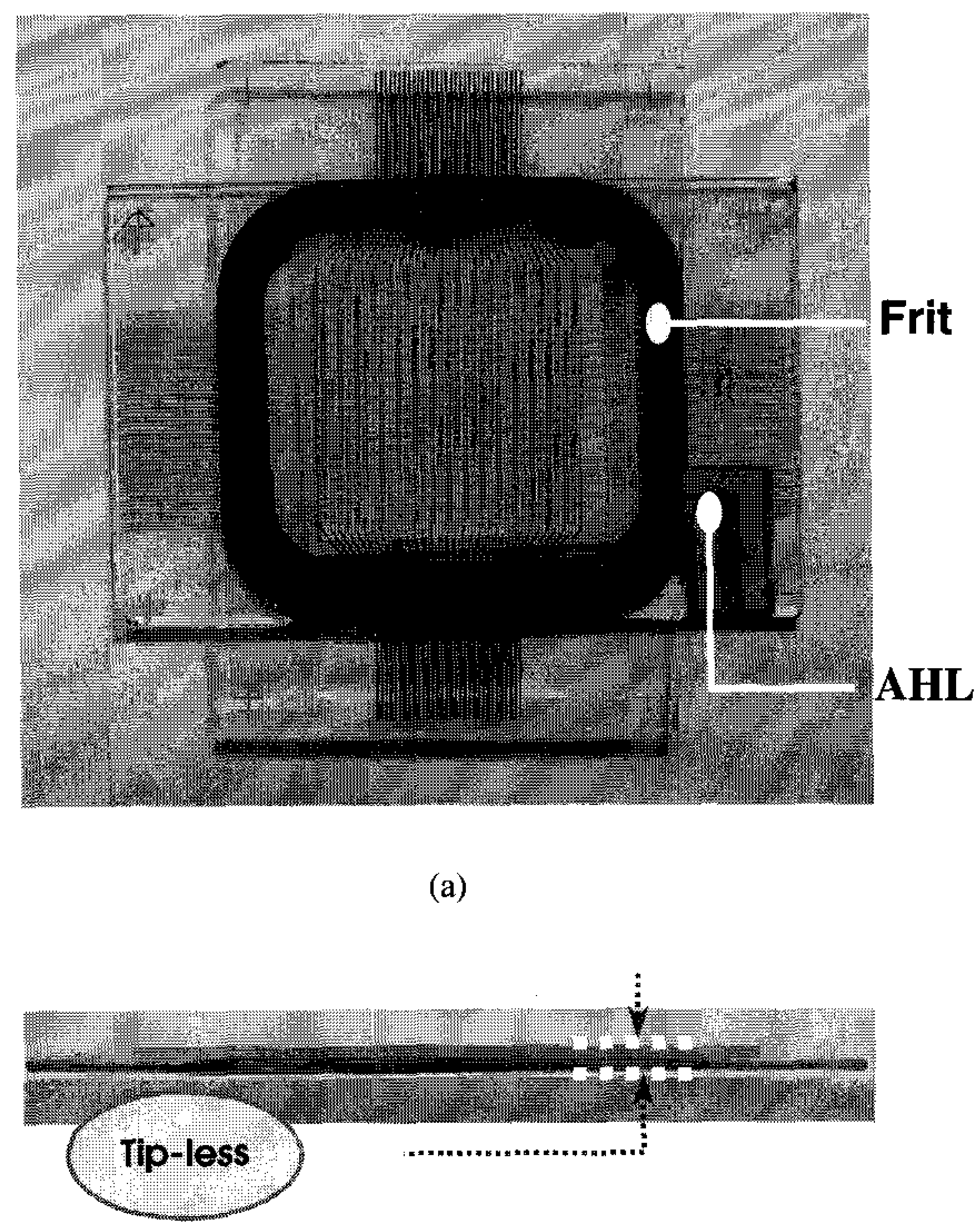

Fig. 3. Operational tubeless-type PDP panel sealed by using the vacuum in-line sealing technology : (a) front-view and (b) side-view.

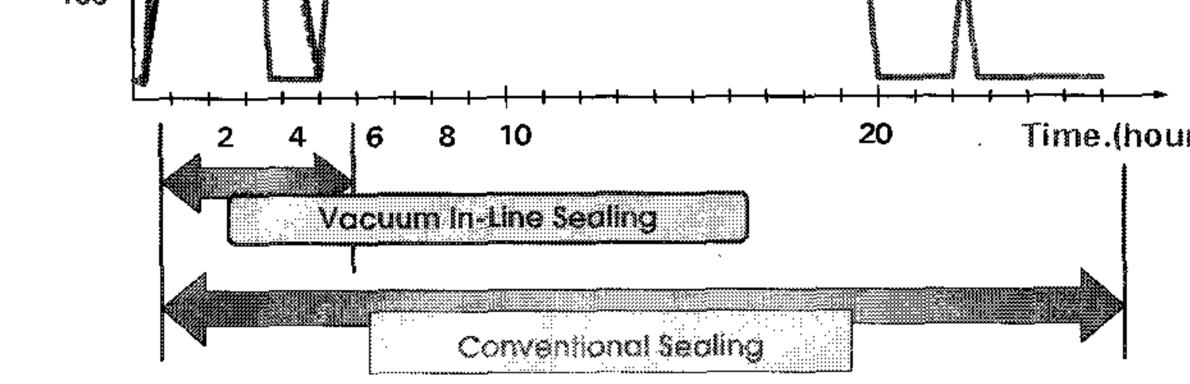

Fig. 4. Comparison of the sealing temperature cycles between a conventional and newly developed vacuum in-line method.

the front glass plate and rear glass plate were loaded into a vacuum chamber, facing each other with a gap distance of 200 μm. A high vacuum level was obtained by using a turbomolecular pump. The base vacuum level prior to the discharge gas filling was controlled by pumping and/or an intentional leaking through a leak valve.

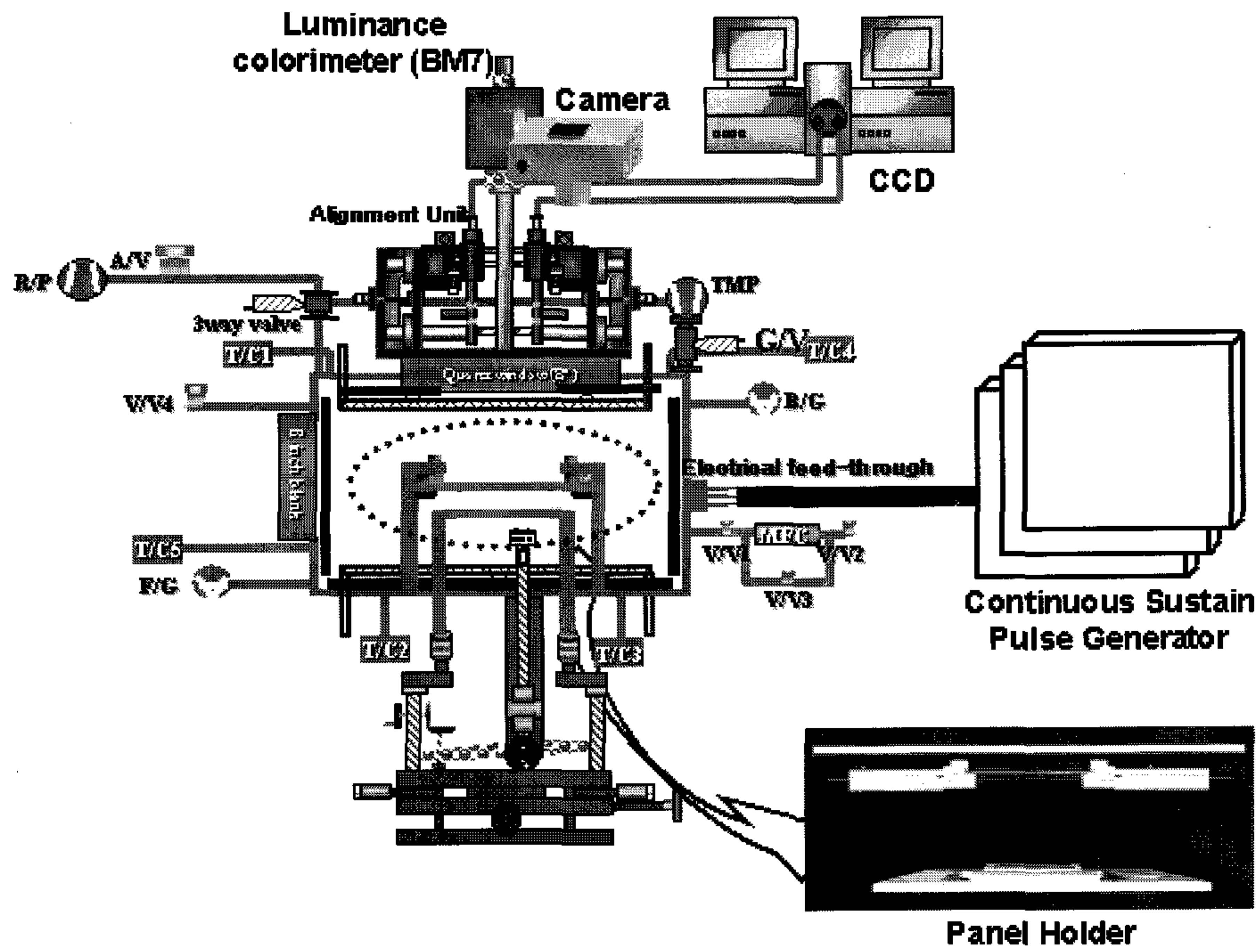

Fig. 5. Block diagram of system for vacuum-in line sealing and in-line characterization of PDP and that which was employed in this study.

First of all, we have observed the electrical and optical characteristics of PDP at a base vacuum level of 1.33 × 10^{-1} Pa. Once this vacuum level was reached, a gate valve of turbomolecular pump was closed and the mixture gas of Ne with 4 % Xe was introduced into the chamber until the gas pressure indicated by a pressure gauge reached the predetermined pressure. In this experiment, the gas pressure was varied from 2.667 × 10^4 to 5.333 × 10^4 Pa with a step of 6.666 × 10^3 Pa. In order to obtain the equilibrium gas pressure between two glass plates consisting the PDP panel, a stabilization time was given for 10minutes at the pressure. Driving pulses were supplied to the X(Sustain) and Y(Scan & Sustain) electrodes of the front glass plate and Z(address) electrodes of the rear glass plate were maintained at the ground level and the circuit connected to panel through electrical feed-through. Frequency of X and Y pulses was 11 kHz, the positive width of the pulse was 7.3 μsec. and the amplitude was varied depending on the conditions.

Second, we have repeated the same procedures for a base vacuum level of 1.33 × 10^{-4} Pa and compared with those of 1.33 × 10^{-1} Pa. In these experiments, the firing voltage and the luminous efficiency were measured at room temperature.

Fig. 5 shows the system set-up for the vacuum in-line sealing and in-line characterization and system used in this study. The heating of two glass plates was conducted by using an infrared light source consisting of tubular heating arrays. After reaching the predetermined temperature, the two panels were put into contact by using positional controls, that is, the lower glass plate was moved up via a x-y-z manipulator until it touched the upper glass plate. The manipulator was applies at sufficient pressure to seal the two plates together. An alignment system with two CCD camera views was also equipped.

3. Results and Discussion

First, the plasma gas was introduced into the panel when the base vacuum level of the chamber reached 1.33 × 10^{-1} Pa. When full cell was turned on, the voltage for ignition of plasma discharge was measured depending on the discharge gas pressure which is shown in Fig. 7.

As shown in the figure, the firing voltage increased from 312 to 343 V as the gas pressure was increased. At

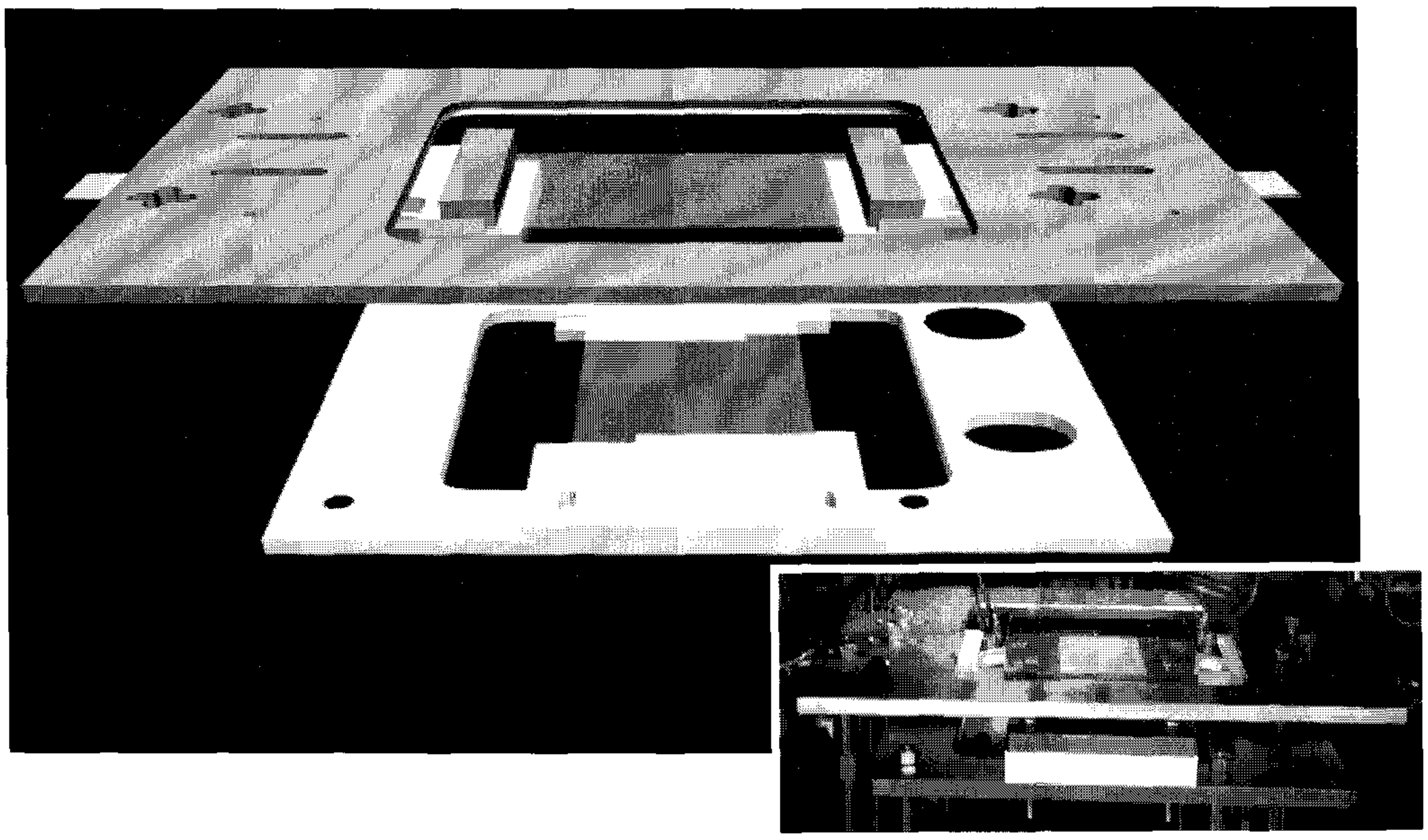

Fig. 6. PDP panel loaded into the vacuum in-line sealing and characterization chamber.

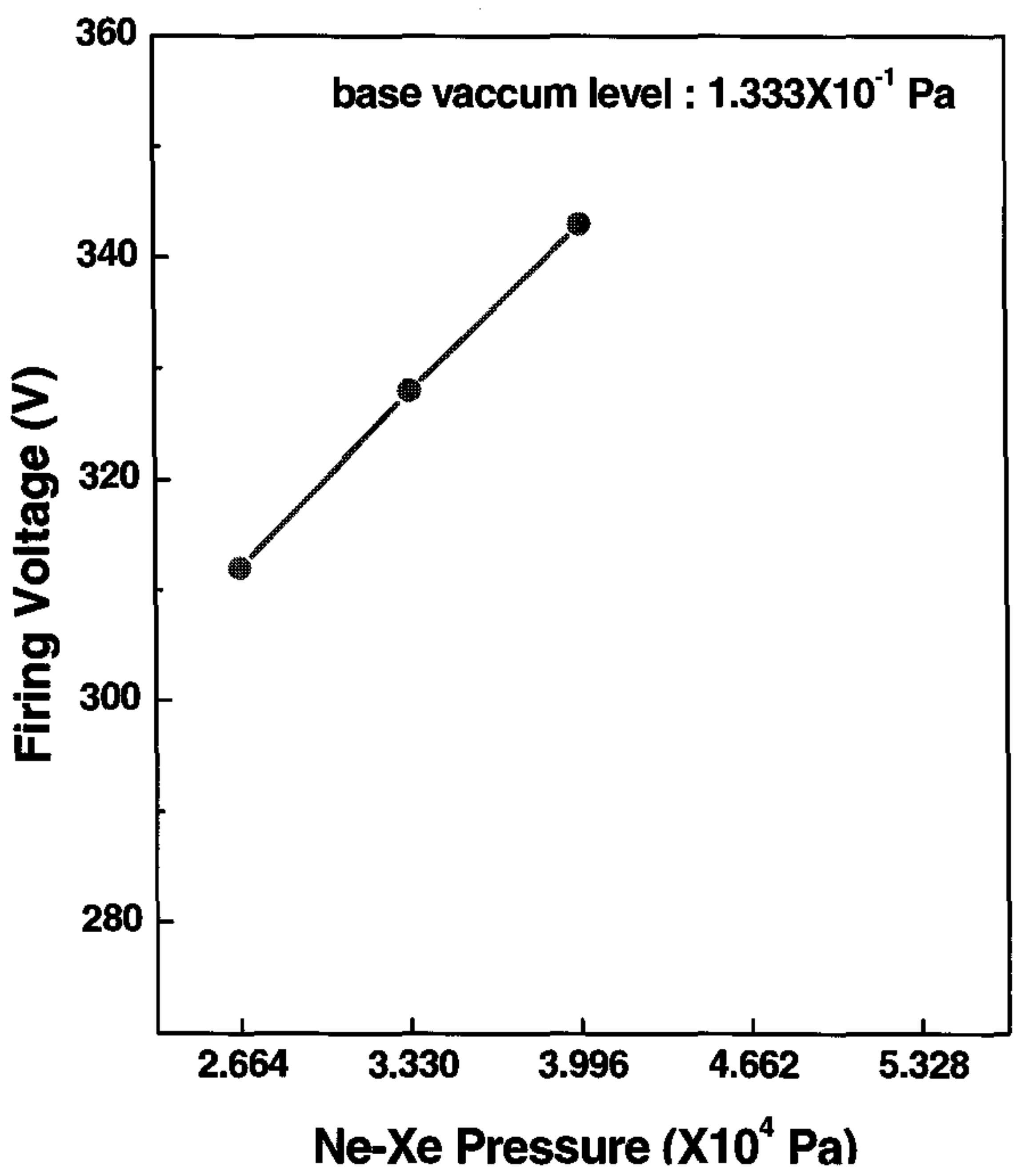

Fig. 7. Firing voltage turning on the full cells depends on the discharge gas pressure when the base vacuum level was 1.333 $\times$ 10^{-1} Pa at room temperature.

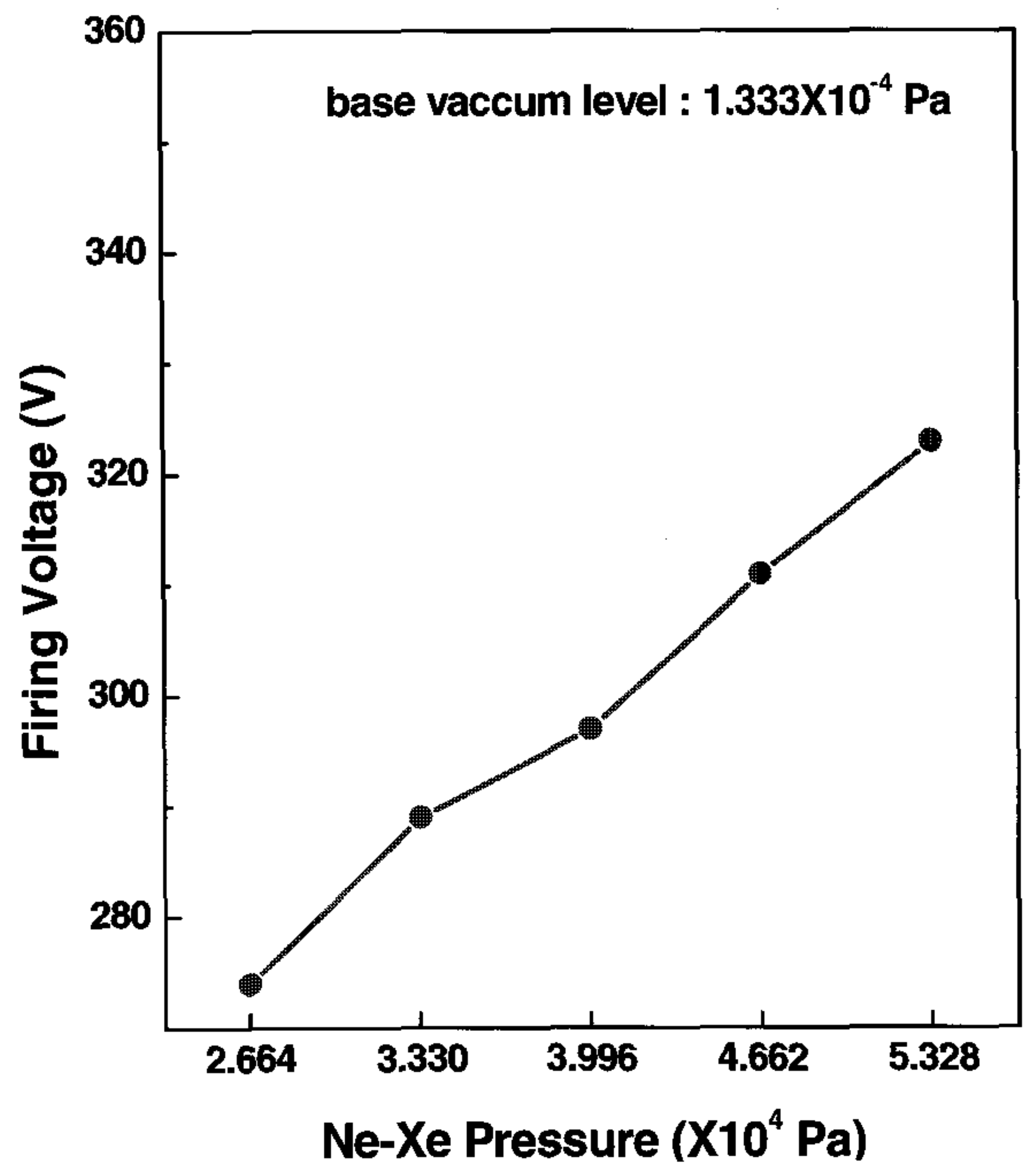

Fig. 8. The firing voltage turning on the full cells depends on the discharge gas pressure when the base vacuum level was 1.333 $\times$ 10^{-4} Pa at room temperature.

a base vacuum level of 1.33 $\times$ 10^{-4} Pa, the plasma gas was evacuated and the chamber was vented. Again, the chamber was pumped until the vacuum level arrived at 1.33 $\times$ 10^{-4} Pa. Subsequently, discharge gas was introduced and the driving pulses were supplied after a holding time of 10min at a given pressure. The measured firing voltages are shown in Fig. 8. Compared to the results at 1.33 $\times$ 10^{-1} Pa, the firing voltages were reduced significantly. As shown, the firing voltage was with in the range of 278 and 324V as the gas pressure increased from 2.667 $\times$ 10^4 to 5.333 $\times$ 10^4 Pa with a step increase of 6.666 $\times$ 10^3 Pa.

At the sustaining voltages of 255, 285, and 330 V, luminance was measured by the in-line colorimeter for

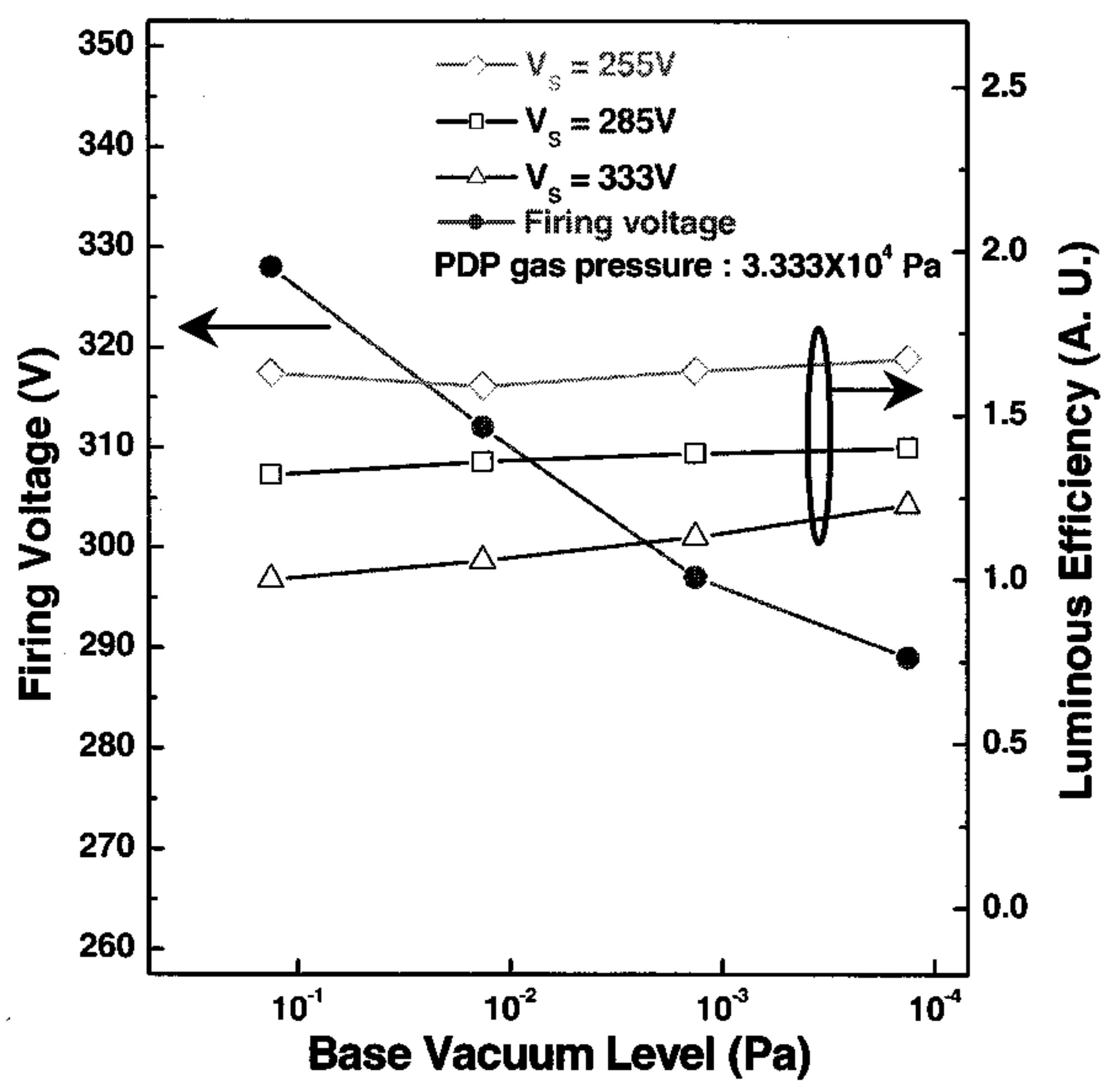

Fig. 9. The base vacuum level effects on the luminous efficiency and the firing voltage. The operating pulses were 255, 285, and 330V with a frequency of 11.1 kHz at room temperature when full cells was turned on.

all the conditions. Fig. 9 shows the variation of the firing voltage and the measured luminous efficiency depending on the four different base vacuum levels. It can be seen from the figure that the better base vacuum level can improving the luminous efficiency slightly as well as reduing the firing voltage significantly.

4. Conclusion

In this study, we have discussed PDPs sealed by vacuum in-line sealing technology and demonstrated that higher base vacuum level is required for improving electrical and optical characteristics. The firing voltage was significantly reduced as the base vacuum level increased. In addition, we found that the luminous efficiency was affected by the base vacuum level, that is, although that is small, the better base vacuum level the improved luminous efficiency. Therefore, we propose the vacuum in-line sealing technology instead of the conventional tabulation furnace sealing technology because the vacuum in-line sealing technology can ultimately provide the fundamental solution for reducing the driving voltage level and enhancing the efficiency of the PDP panel due to a pure gas environment.

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