

Effects of Base Vacuum Level on Discharge Characteristics in Vacuum In-Line Sealing Process for High Efficient PDP

Sang Jik Kwon* and Chan-Kyu Jang

Abstract

Effects of base vacuum level on the electrical and optical characteristics of the plasma display panel (PDP) were investigated. The relationship between efficiency and base vacuum level before filling discharge gas was analyzed. For the base vacuum level of 1×10^{-4} torr, firing voltage of a 2-inch diagonal PDP panel was 232 V at the discharge gas pressure of 400 torr and luminous efficiency was 1.5 lm/W at 180V sustaining pulse. On the other hand for 1×10^{-6} torr, the firing voltage was reduced to 215 V and luminous efficiency was improved considerably to 2.5 lm/W. We successfully demonstrated the smooth operation of tip-less PDP fabricated using vacuum in-line sealing method.

Keywords : PDP, Vacuum In-Line Sealing, High Efficiency

1. Introduction

One of most successful technologies for large-format displays is the plasma display panel (PDP). However, for PDP to grasp a bigger share of the large-size display market, it is of great importance to reduce the manufacturing cost and improve its luminous efficiency. Among the issues related to the reduction of PDP fabrication cost, there is room for sealing process to improve. In the conventional sealing method, first, two plates are sealed together using frit sealing under the atmospheric environment. Then, the panel is evacuated by a high vacuum pump through a glass tube sealed to a corner of rear glass plate, of which the dimension is typically a few tens of cm in length and approximately ~2 mm in diameter. After baking for approximately 12 hours, a mixture of discharge gas is introduced into the panel and the glass tube is tipped-off. The sealing process normalry takes 15 hours and the obtained base vacuum level is limited by the pumping conductance of the panel, mainly attributed to the rectangular nozzle-shaped structure defined by the barrier ribs and the closely spaced glass plates. In the PDP panel of diagonal size of 40 inch and dimensions of 150 μm gap between the two glass plates and 320 μm pitch between barrier ribs, the base vacuum level at the panel center was estimated to be less than 1×10^{-3} torr [1].

The most promising method for obtaining the initial high vacuum level inside the panel at a minimum sealing process time is the vacuum in-line sealing technology, with which two glass plates are sealed in a high vacuum chamber. In previous works [2], we have demonstrated the feasibility of the vacuum in-line sealing technology by measuring characteristics of PDP fabricated using the technology.

In this study, the effects of base vacuum level inside the panel prior to gas filling on operation voltage and luminous efficiency were investigated. The panel has stripe type cell structure. The panel was placed in a vacuum chamber and driven by a driver circuit interfaced to the chamber via an electrical feed-through. Luminous efficiency was observed using the in-situ measurement from the luminous colorimeter equipped on the top-side view port.

2. Experimental Procedures

The PDP panel used in our study is composed of two plates of PD-200(ASAHI glass, Japan) substrates. The dimension of the glass plate is 6 cm × 9 cm 2.8 mm. The

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size of active area is 3.5 cm × 3.5 cm. For the front panel, bus electrodes were printed on the ITO-patterned glass using screen printing method. Then, dielectric layer was printed over the bus electrodes with a thickness of about 24 μm, and then MgO layer was deposited using an e-beam evaporator on the dielectric layer with a thickness of 5,000 Å. For the rear panel, first address electrodes were printed on the glass substrate, and the dielectric layer of which the thickness is about 24 μm was printed over the address electrodes. Then, the barrier ribs with a height of 120 μm were printed on the dielectric layer using screen printing method, and finally the phosphor layer was printed between the barrier ribs.

Fig. 1 shows the system set-up for the vacuum in-line sealing and in-line characterization system used in this study. In order to investigate the effects of base vacuum level on the electrical and optical characteristics of PDP, the front glass plate and the rear glass plate were loaded into a vacuum chamber, facing each other with a gap distance of 200 μm. The chamber was evacuated using a turbomolecular pump. The base vacuum level before discharge gas filling was controlled by an evacuation level and an intentional leaking through a leak valve.

First of all, we observed the electrical and optical characteristics of PDP at the base vacuum level of 1×10^{-3} torr. 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 measured by a pressure gauge reached a predetermined pressure. Driving pulses were supplied to X(Sustain) and Y(Scan & Sustain) electrodes of the front glass plate, Z(address) electrodes of the rear glass plate were maintained at ground level and the circuit was connected to panel through electrical feed-through. The frequency of X and Y pulses was 50 kHz and the positive width of the pulse was 3.0 μs. The amplitude was varied depending on the conditions. The measurements were taken without annealing. Next, we repeated the same procedures for base vacuum levels of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} torr, respectively. In these experiments, the firing voltage and the efficiency were measured at room temperature.

3. Results and Discussion

For the sealing of PDP panel, the front panel and the rear panel were loaded into the so-called 'vacuum in-line sealing chamber', facing each other at suitable distance to maintatin a sufficient pumping conductance. The sealing chamber was evacuated using a turbomolecular pump, until a high vacuum level was reached prior to plasma gas filling, The heating of two glass plates was done by using an infrared light source consisting of tubular heating arrays. After the predetermined temperature for melting the preformed seal-frit was reached two panels put into contact using positional controls, that is, the lower glass plate was

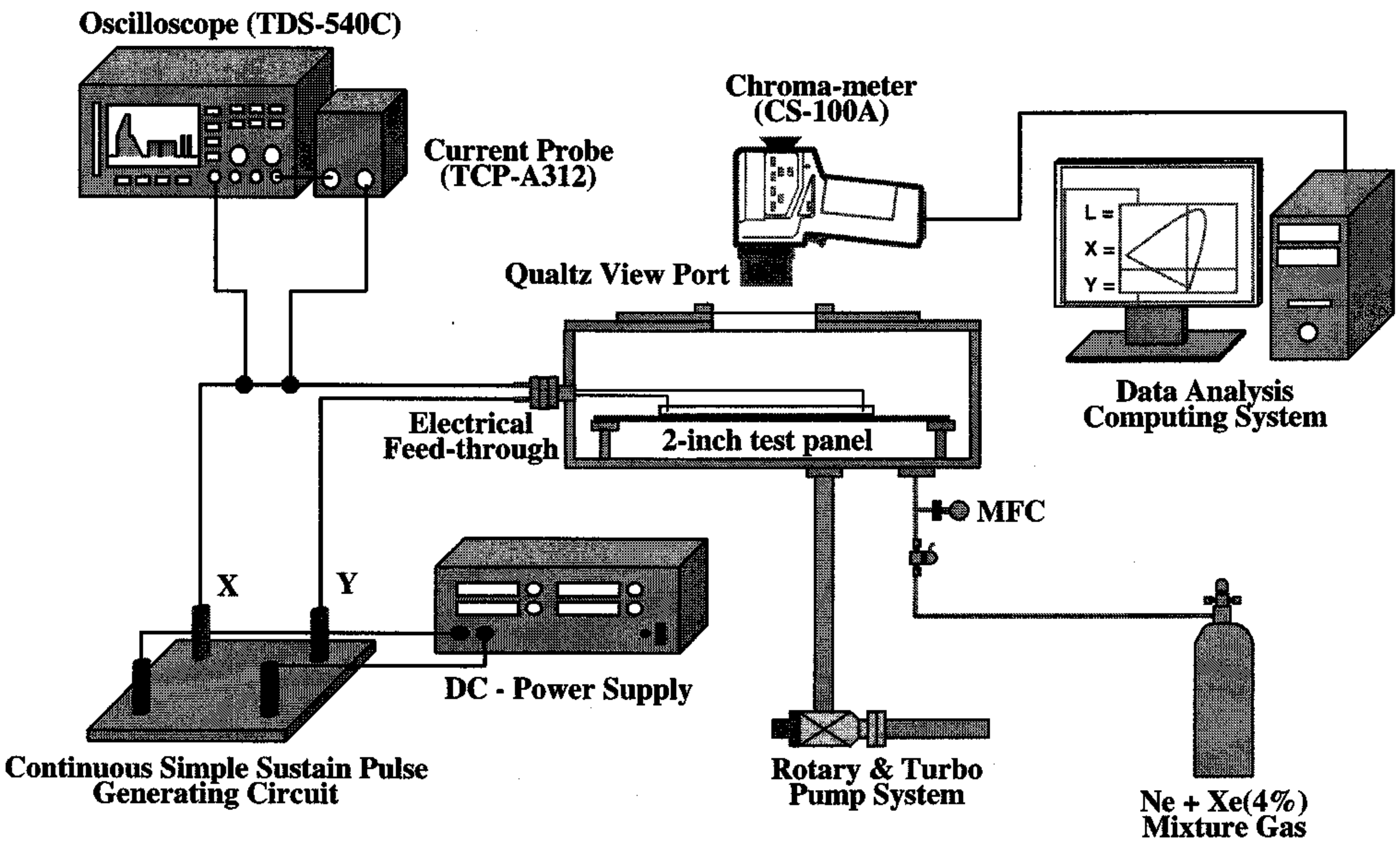


Fig. 1. Block diagram of the system for the vacuum-in line sealing and the in-line characterization of PDP.

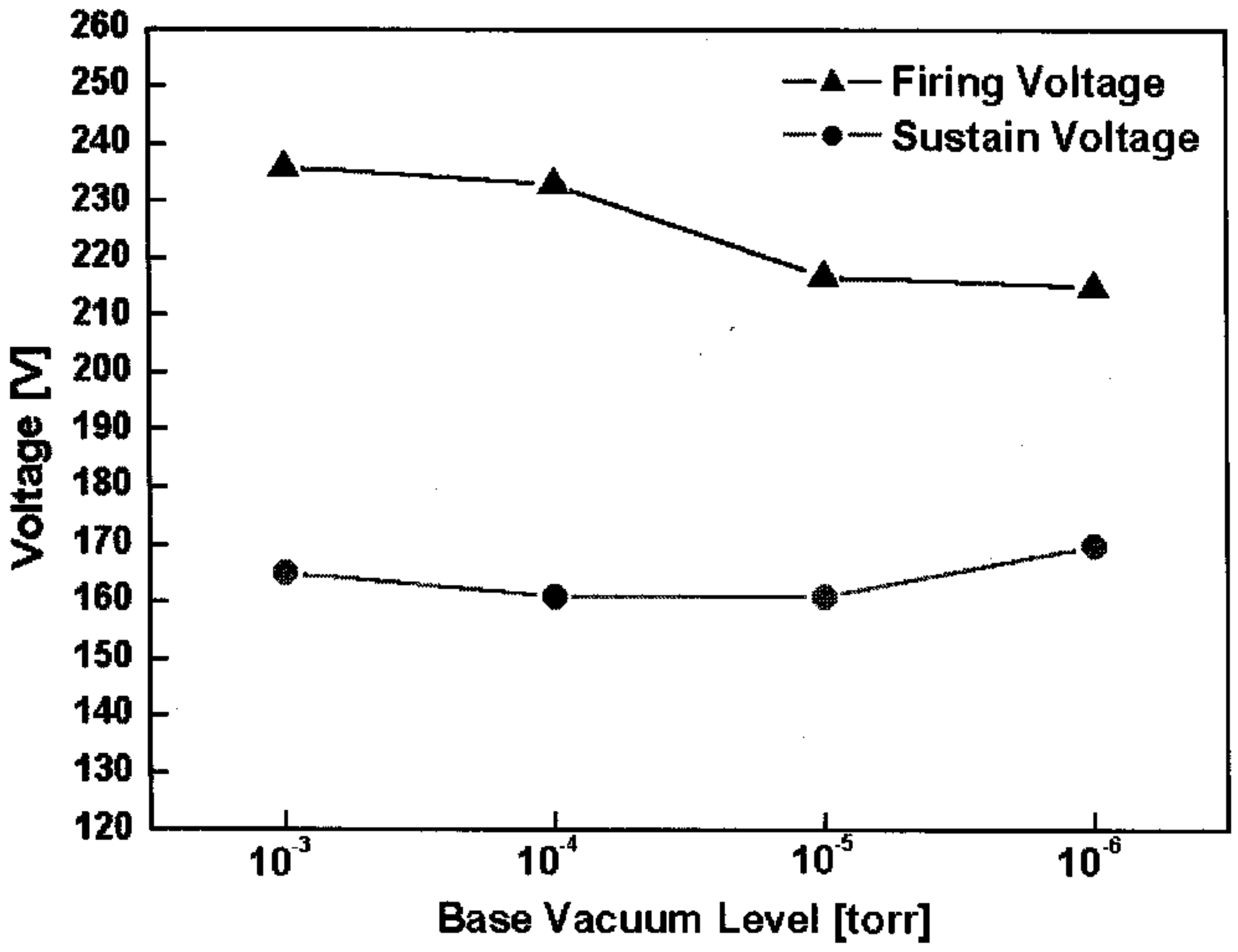


Fig. 2. Firing voltage dependance on the base vacuum level (at 400 torr of Ne- 4 % Xe).

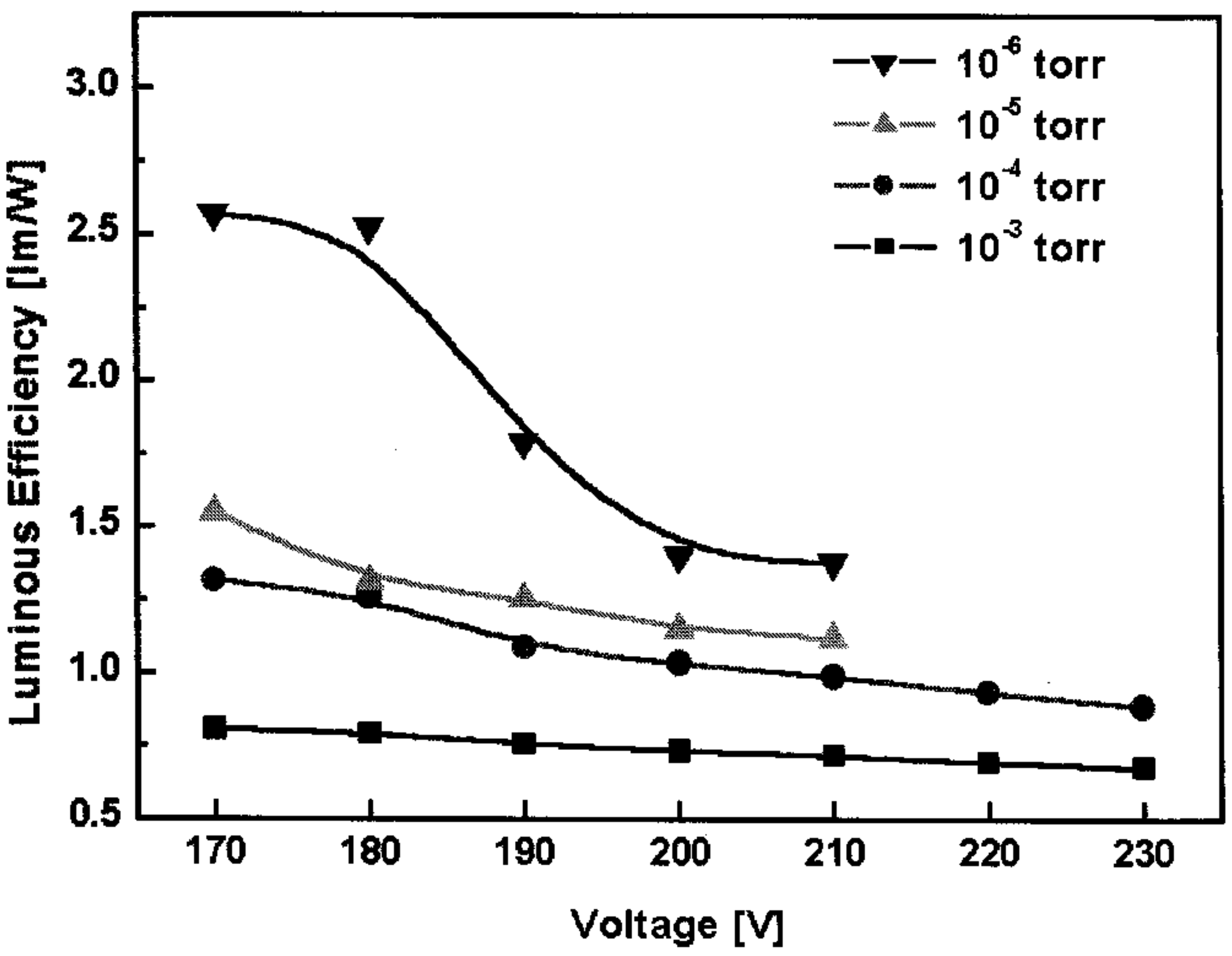


Fig. 3. Effects of base vacuum level on the luminous efficiency.

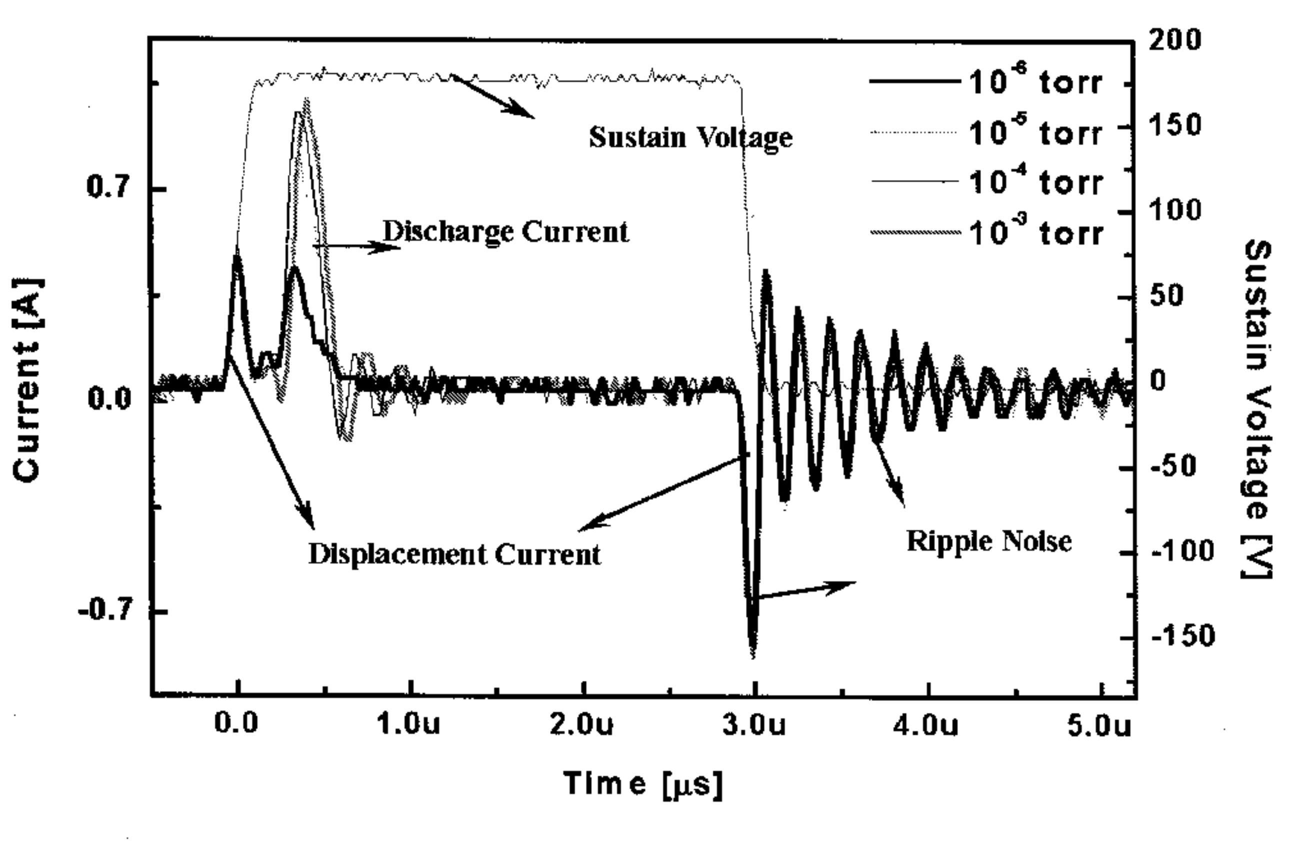
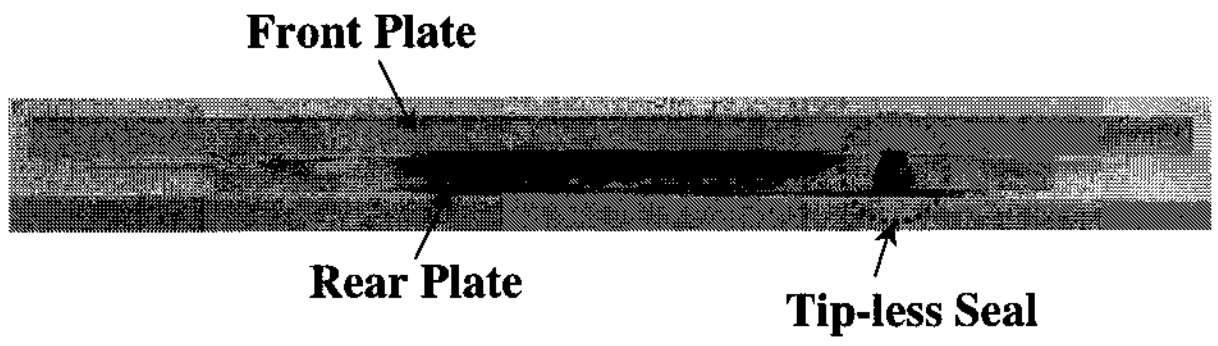
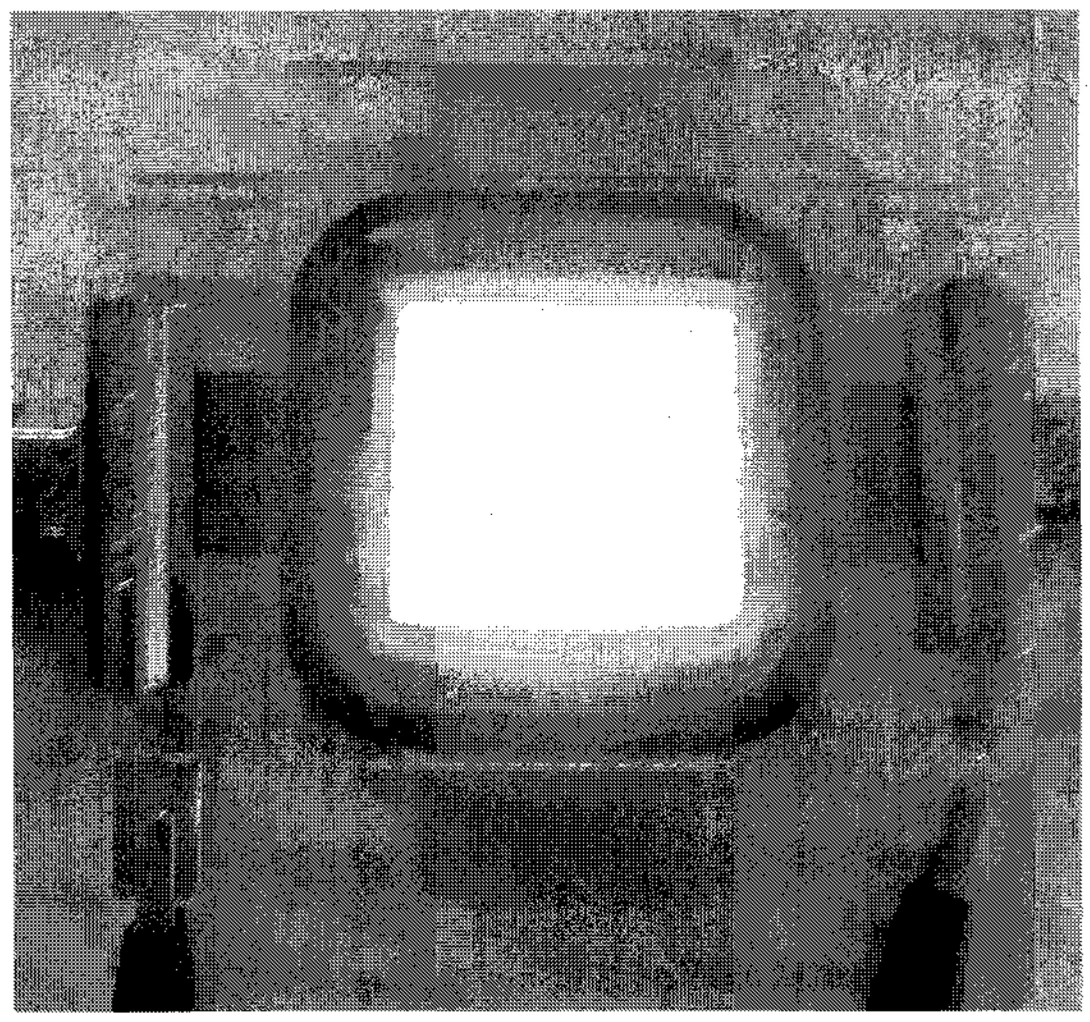


Fig. 4. Discharge current waveforms with the base vacuum level (sustain pulse: 180 V).



(a)



(b)

Fig. 5. An operational tubeless-type PDP panel sealed using the vacuum in-line sealing technology: (a) side-view and (b) front-view.

moved up via a x-y-z manipulator until it touched the upper glass plate. The manipulator applied an enough pressure to seal the two plates together. An alignment system with two CCD camera views was installed. Finally, the discharge gas with Ne-Xe(4 vol %) mixture was filled into to 400 torr. The tubeless-type PDP panel fabricated using this vacuum in-line sealing technology is shown in Fig. 5. A comparison of the sealing process cycles between the conventional and this newly developed vacuum in-line method is shown in Fig. 6. From this figure, it can be seen that the vacuum in-line sealing technology can reduce prominently the total sealing time and the temperature cycles as well as improvement of the PDP discharge characteristics.

Fig. 2 shows the variation of the firing voltage and the sustaining voltage at different levels of base vacuum prior to discharge gas filling. It can be seen from this figure that the firing voltage can be reduced effectively by increasing the base vacuum level. However, the sustaining voltage did not change significantly with the base vacuum level. The luminous efficiency was improved significantly with the increase in the base vacuum level as shown in Fig. 3, particularly near 1×10^{-5} torr range. However, for the color point coordinate, the degree of green color did not change significantly with the base vacuum level. This result shows that the improvement of the luminous efficiency was not the result of the change of the color point coordinate but the improvement of the luminance. Moreover, it is well known that the discharge characteristics are affected by impurity species and concentration in the discharge gas, compositions and pressure of the gas mixture, and the crystallinity and the density of MgO protective layer [3-6]. Particularly, it has been reported that the hydroxyl groups or absorbed water affects the discharge characteristics considerably [7]. In this study, the reduced firing voltage and improved luminous efficiency at higher base vacuum level might be attributed to the dehydration of the hydroxyl groups and removal of absorbed water and other impurity

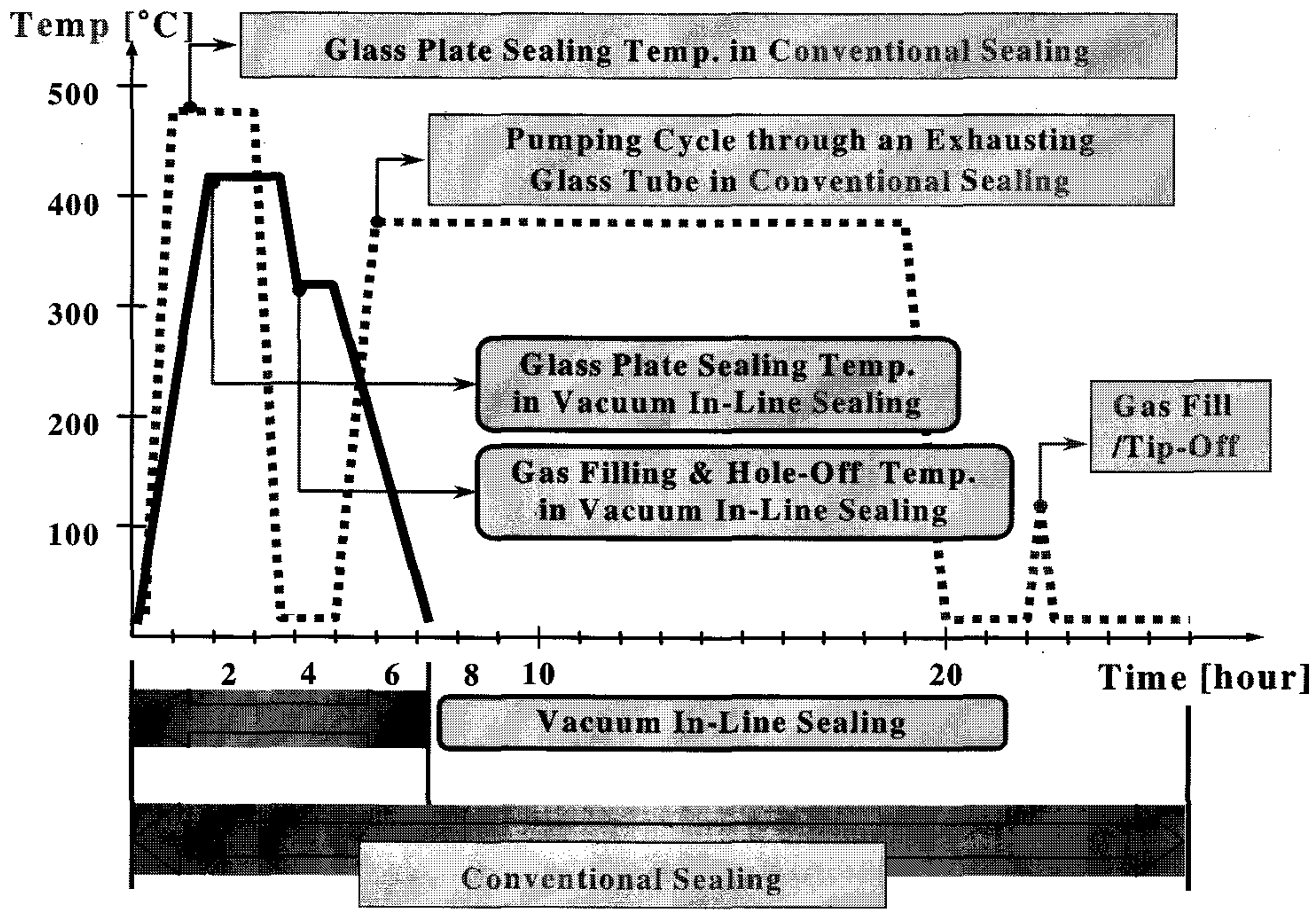


Fig. 6. Comparison of the sealing temperature cycles between a conventional and the newly developed vacuum in-line sealing method.

Table 1. Color point coordinates depending on the base vacuum level (at 400 torr of Ne- 4% Xe).

Base vacuum level	1×10^{-3} torr		1×10^{-4} torr		1×10^{-5} torr		1×10^{-6} torr	
Color point coordinate	x	y	x	y	x	y	x	y
170 V	0.282	0.656	0.264	0.677	0.259	0.680	0.257	0.682
180 V	0.278	0.660	0.261	0.678	0.258	0.681	0.256	0.683
190 V	0.277	0.660	0.261	0.678	0.257	0.682	0.256	0.684
200 V	0.275	0.663	0.262	0.678	0.257	0.682	0.255	0.685
210 V	0.276	0.662	0.262	0.678	0.256	0.684	0.254	0.686
220 V	0.277	0.661	0.262	0.678				
230 V	0.277	0.661	0.261	0.679				
Average	0.277	0.660	0.262	0.678	0.258	0.682	0.256	0.684

gas.

Fig. 4 shows the oscilloscope traces of the sustain discharge current depending on the base vacuum level. The discharge current starts to increase 0.3 μs after the application of the sustain pulse for all cases. However, as the base vacuum level increases, the peak current occurs earlier and the total amount of the induced discharge current reduces. This might be the main reason for the increase in the efficiency as the vacuum level improves.

4. Conclusion

We have observed effects on the electrical and optical characteristics of the PDP panel depending on the base vacuum level obtained by the pump evacuation before plasma gas filling were investigated. The firing voltage was significantly reduced as the base vacuum level increased from 1×10^{-3} to 1×10^{-6} torr. In addition, the luminous efficiency is affected by the base vacuum level. That is, the higher the base vacuum level, the better the luminous efficiency. These results indicate that, instead of the conventional tabulation furnace sealing, the vacuum in-line sealing technology could be the fundamental solution to enhancing the efficiency of the PDP due to the dehydration of the hydroxyl groups, absorbed water and other impurity gases, as well as the cost reduction effect due to a short sealing time.

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