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# Effects of the Impurity Gases on the Characteristics of ac PDP

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## Abstract

The luminance and discharge characteristics of ac PDP may be significantly affected by a small amount of impurity gas in working gas. These impurity gases such as $O_2$, O, C and $H_2$ can be mixed in the manufacturing and /or discharge process. In this paper a small amount of impurity gas in acPDP are introduced quantitatively and the relationship between the amount of impurity gas and the luminance/discharge characteristics are investigated. The luminous efficiency decreased seriously with increase in the partial pressure of impurity gases, especially in $H_2$, $O_2$ and $CO_2$. Under the condition of the impurity gas ratio of $2\times10^{-3}$ for Ar, $N_2$, $H_2$, $CO_2$ and $O_2$, the luminous efficiency decreased about 8%, 8%, 32%, 36% and 50%, respectively.


**Key Words** : Ac PDP, Impurity gas, luminance/discharge characteristics

## 1. INTRODUCTION

AC plasma display panel (PDP) is a flat panel display, which utilizes gas discharge. Fig. 1 shows the principle structure of a discharge cell in ac PDP. The size of a discharge cell is about 0.3mm×1mm×0.15mm(height). The tri-primary color(R, G, B) is obtained from RGB phosphors excited by vacuum ultra-violet photons emitted from gas discharge. AC PDP is now being one of the most leading candidates for the large area wall hanging TVs.

It still has to be improved, however, in terms of cost, luminous efficiency and so on [1-15]. Especially, one of the serious problems is the decrease of the luminance and luminous efficiency caused by contamination of the working gas. The working gas in PDP must be chemically stable and has to emit an intense UV (Ultra-violet) [16]. In order to meet these conditions, He, Ne or Xe mixture gases are used at pressures between 300 and 500 Torr. If the impurity gases such as $O_2$, O, $CO_2$ and $H_2$ are included in working gas, they may increase the discharge voltage, contaminate the MgO layer and decrease the UV intensity, that lead to affecting the PDPs performance. The impurity gases are mainly generated from the manufacturing process and discharge process [17].

In this study, we investigated the effects of impurity gas on the luminance, luminous

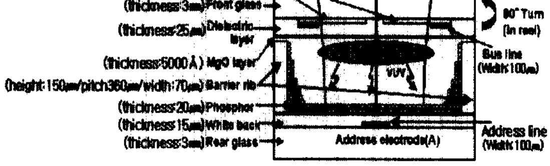


**Fig. 1.** Principal structure of a discharge cell in ac PDP.

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efficiency and discharge characteristics in ac PDP after introducing impurity gases such as Ar, $N_2$, $O_2$, $H_2$ and $CO_2$..

## 2. EXPERIMENTS

Table 1 shows the specification of 4-inch test PDP used in this study with VGA resolution.

Figure 2 shows the schematic diagram of discharge test chamber and driving circuit for measuring the electrical and optical characteristics of test panel. The test chamber is connected to the main chamber, which is a cylindrical type of 200mm diameter and 80mm height with molecular pump vacuum system. The upper part of test chamber has a quartz window to investigate the optical characteristics[1-6].

The panel in the test chamber were baked in vacuum at 350℃ for two hours, exhausted up to ~10-7 Torr by molecular pump, and then a given impurity gas and working gas (He+Ne70%+ Xe4 %) were mixed in the main chamber. After that, the mixed gas were injected in the test chamber through the connection valve. The ratio of impurity gas to the working gas were varied in the range of $2\times10^{-3}\sim10\times10^{-3}$. After the test chamber was filled with discharge gas of 400Torr, the firing voltage, sustaining voltage, luminance and discharge current waveform of the test panels are tested. The applied ac pulse voltage was 210V with 50kHz and the duty ratio was 0.5[5-7].

**Table 1.** Specification of 4-inch ac PDP

| Front panel | | Rear panel | |
|---|---|---|---|
| ITO width | 310 ㎛ | Address electrode width | 100 ㎛ |
| ITO gap | 60 ㎛ | White back thickness | 150 ㎛ |
| Bus width | 100 ㎛ | Rib height | 150 ㎛ |
| Dielectric thickness | 25 ㎛ | Rib pitch | 360 ㎛ |
| MgO thickness | 5000Å | Rib width | 70 ㎛ |
| | | Phosphor thickness | 20 ㎛ |

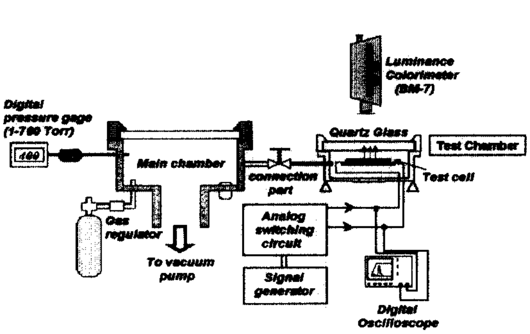


**Fig. 2.** The schematic diagram of test chamber for testing.

## 3. RESULTS AND DISCUSSIONS

Figure 3 shows the effect of impurity on the discharge voltage compared with that of the pure working gas as a standard. As shown in Fig. 3, the discharge voltage increased significantly with the partial pressure of $O_2$ and $CO_2$ gases, whereas slightly with Ar, $N_2$ and $H_2$. Especially the sudden decrease in the discharge voltage with Ar at 400Torr may be due to the Penning effect with Ne gas[18].

Under the condition of the impurity gas ratio $2\times10^{-3}$, the discharge voltage for the impurity

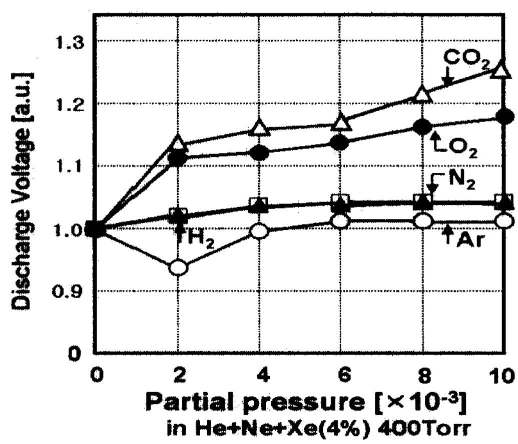


**Fig. 3.** Effect of impurity gas on the discharge voltage of ac PDP.

gas of $CO_2$, $O_2$, $N_2$, $H_2$ and Ar increased about 15%, 12%, 4%, 2.5% and 8%, respectively. The effect of impurity gases such as $CO_2$ and $O_2$ on the electrical and luminous characteristics of ac PDP may come from the negative-ion formation by the electro-negative gases [19]. It is well known that the negative ions formation gas suppresses the spark breakdown by forming negative ions, which lead to decrease electron temperature. However, in the discharge plasma, $CO_2$ gas reacts with MgO, and makes $MgCO_3$, which is irreversible reaction. Furthermore, the $MgCO_3$ has low $\gamma$-coefficient than MgO. The highest discharge voltage of $CO_2$ in Fig. 3 may be due to the $MgCO_3$ on the MgO surface[20].

Figure 4 shows the effect of impurity gases on the luminance. As shown in Fig. 4, the luminance decreased significantly with the increase of the impurity gases, especially in $H_2$, $O_2$ and $CO_2$. Under the condition of the impurity gas ratio of $2\times10^{-3}$ for the Ar, $N_2$, $H_2$, $CO_2$ and $O_2$, the luminance decreased about 10%, 10%, 40%, 45% and 60%, respectively.

Figure 5 shows the effect of the given impurity gas on the luminous efficiency, which are very similar to those shown in Fig. 4. The luminous efficiency was calculated using the following formula.

$$\text{Luminous efficiency (lm/W)} = \frac{\pi \times \text{Luminance (cd/m}^2) \times \text{Display Area (m}^2)}{\text{Power consumption (W)}}$$

$$\text{Power consumption (W)} = 2f \int_0^{T/2} V_s(t)\,(I_{on}(t) - I_{off}(t))\,dt$$

Where, $f$ is the frequency, $T$ is the period, *ion* is the total current and *ioff* is the displacement current [17]. Under the condition of the impurity gas ratio of $2\times10^{-3}$ for the impurity gas of Ar, $N_2$, $H_2$, $CO_2$ and $O_2$, the luminous efficiency decreased about 8%, 8%, 32%, 36% and 50%, respectively.

As mentioned above, the effect of impurity gas such as $CO_2$, $O_2$, and $H_2$ on the discharge voltage, luminance and luminous efficiency are very significant. Here, it may be note worthy to point out whether the characteristics of discharge voltage and luminance of ac PDP are recovered or not when the contaminated gas is changed with a new working gas.

Figure 6 and 7 show the discharge voltage and luminance characteristics when the contaminated working gas is degassed and refilled with a new working gas of He+Ne70%+Xe4% with 400Torr. As shown in Fig. 6 and 7, the discharge voltage and luminance characteristics with N2, Ar and $H_2$ are almost recovered, whereas those with $O_2$

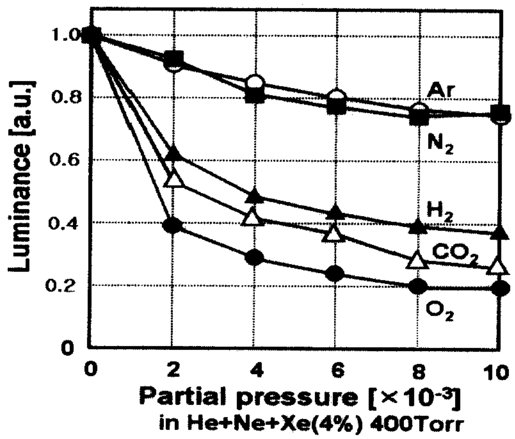


**Fig. 4.** Effect of impurity gas on the luminance of ac PDP.

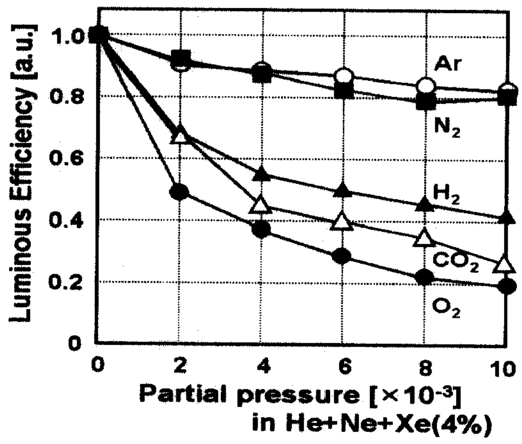


**Fig. 5.** Effect of impurity gas on the luminous efficiency of ac PDP.

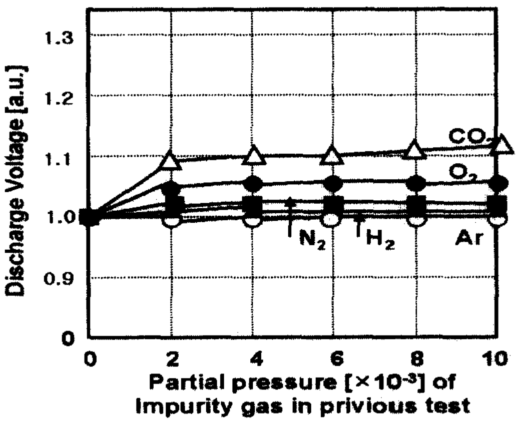


Fig. 6. Discharge inception voltage characteristics when the given contaminated gas is changed with new working gas after testing.

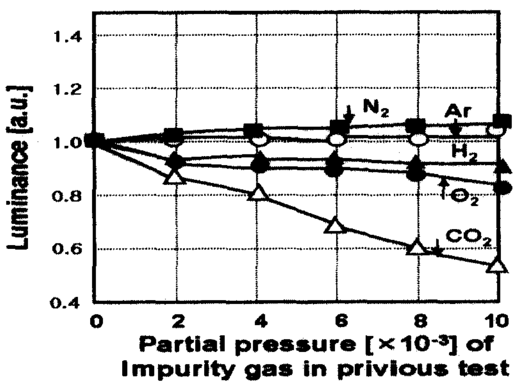


Fig. 7. Luminance characteristics when the given contaminated gas is changed with working gas after testing.

and $CO_2$ are not. The reasons may be due to considered as follows.

As mentioned in Fig. 3, the $CO_2$ gas makes $MgCO_3$ on the MgO. Furthermore, this reaction is irreversible [20]. Therefore, the discharge andluminance characteristics are not recovered. Especially, $O_2$ gas also degassed mostly with other impurity gasses. However, the $O_2$, or O gas from the dissociation of $O_2$ gas in the discharge plasma have high electron affinity coefficient as shown in Table 2. Therefore, the small amount of $O_2$ gas affects significantly on

Table 2. Electron affinity of some important gases.

| Kind of atom molecule | Electron affinity[eV] |
|---|---|
| F | 3.94 |
| B | 3.70 |
| Br | 3.54 |
| I | 3.22 |
| O | 3.80 |
| $O_2$ | ~1.0 |
| H | 0.75 |
| $H_2$ | 0.76 |
| N | ~0.04 |
| $N_2$ | 0.04 |
| Inert gases | ≒0 |

the discharge voltage and luminance characteristics.

## 4. CONCLUSION

In this paper a small amount of impurity gas in ac PDP are introduced quantitatively and the relationship between the amount of impurity gas and the luminance/discharge characteristics are investigated. The luminous efficiency decreased seriously with increase in the partial pressure of impurity gases, especially in $H_2$, $O_2$ and $CO_2$. Under the condition of the impurity gas ratio of 2¿10-3 for Ar, $N_2$, $H_2$, $CO_2$ and $O_2$, the luminous efficiency decreased about 8%, 8%, 32%, 36% and 50%, respectively.

It is considered that the impurity gas effects on PDP characteristics manly come from the negative- ion formation for $O_2$ and $H_2$, and irreversible $MgCO_3$ formation on the MgO surface for $CO_2$.

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