The effect of Gas Mixture Ratio on Discharge Characteristics of an AC PDP Cell

Hae June Lee, D.-K. Lee, J.-H. Choi, Y.-S. Cho, H-D Park, H.-J. Lee and C.-H. Park
Pusan National University, Pusan 609-735, South Korea

Abstract
Experimental measurements are reported and compared with the results of a two-dimensional fluid simulation for the investigation of the discharge characteristics regarding the change of the mixture ratio of Ne-Xe-He noble gases. The increase of Xe contents results in the increases of luminance and luminous efficiency while it also results in the increase of the breakdown voltage and the discharge time lag. The addition of He gas increases the brightness and the luminance efficiency. When Xe partial pressure is low, the luminance efficiency increases with the amount of He at the same total pressure. When Xe partial pressure is high, however, the luminance efficiency has a maximum value when the partial pressure of He is about 10% of the total pressure for a standard AC PDP cell with Xe fraction of 10~30%.

1. Introduction
Even though plasma display panel is spotlighted as the most promising candidate for large size flat panel displays [1,2], still it is needed to improve the luminance efficiency which is lower than 2 lm/W for commercially manufactured PDPs by now. Therefore, in order to accomplish high luminance efficiency up to the same level as CRT (5 lm/W), many researchers are trying to include high Xe contents and/or to use long gap discharges. It was reported that high luminance efficiency of 5 lm/W was obtained by using 50% Xe gas in Ne base for a 4-inch color PDP test panel [3]. With high Xe contents, not only the luminance efficiency but also sustain margin increases, and the panel lifetime increases. However, with the inclusion of high Xe contents, there are several drawbacks such as the increases of firing and sustain voltages, the decreases of data pulse margin, and the increase of discharge time delay.

In order to exploit the advantages of high Xe contents with minimizing these disadvantages, we started the researches of ternary gas mixture of Ne-Xe-He for high Xe contents. The gas mixture ratio of PDP discharges plays a very important role in discharge characteristics of an AC PDP cell such as operating voltages, brightness, discharge time lag, and luminous efficiency. The mechanisms are complex and complicated. For example, different gas mixture ratio results in the change of the rate coefficients, step ionization, ion mobility, secondary electron emission, Penning effects, and atomic collisions.

In this study, experimental measurements and analysis with two-dimensional fluid simulation are presented for the change of the mixture ratio of Ne-Xe-He noble gases with Xe contents up to 30%. In Sec. 2, the experimental data are presented for firing voltage, voltage margin, brightness, luminance efficiency, and discharge delay time. In Sec. 3, we present the analysis of the gas mixture effect on ionization coefficients and some results of a fluid simulation for ternary gas mixture. Finally, summary and discussions are presented in Sec. 4.

2. Experiments
2.1 Experimental Setup
Figure 1 shows the schematic diagram of the experimental system. It is composed of signal generator, driving circuit, heating system, and oscilloscope for the measurement. The measurements of voltage waveform, current, and discharge time lag were carried out with a digital storage oscilloscope and a current probe.

Table 1 shows the specifications of the panel used in experiment. Our 7-inch test panel corresponds to the commercial 42 inch panel having XGA resolution.

We measured the firing voltage, margin, luminance, and luminous efficiency by changing the ternary mixture ratio of Ne-He-Xe noble gases. At first, we selected the partial pressure of Xe, and after then changed the ratio of partial pressure between He and Ne with the fixed Xe pressure. By using this method, it was possible to minimize the variable parameters during experiment. The mixture ratio of Ne:He is

100:0 ~ 50:50, and Xe gas fraction varies from 4% to 30%.

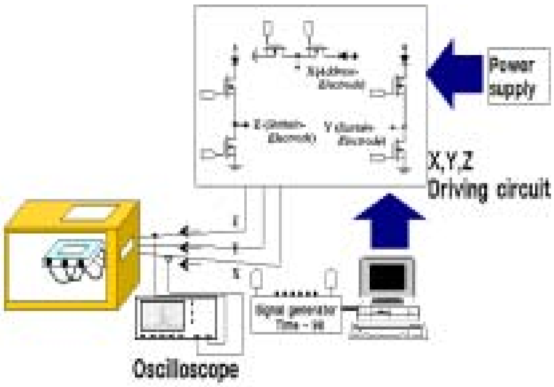

Fig. 1 Schematic diagram of the experimental system

Table 1. The specification of test panel

Bus width	70㎛
ITO width	270㎛
ITO gap	60㎛
Dielectric thickness	40㎛
MgO thickness	8000Å (E-beam evaporation)
Barrier rib width	90㎛
Barrier rib height	130㎛
Phosphor thickness	20㎛
Gas pressure	500 torr

2.2 Experimental Results

Figures 2 and 3 show the firing voltage and the voltage margin with the additional He gas inclusion in Ne-Xe gas mixture. The effects of He gas is not significant on the firing voltage, especially for low Xe contents. However, at high Xe partial pressure of around 30%, the voltage margin decreases with the increase of He gas.

Figures 4 and 5 show the influence of He contents on brightness and luminous efficiency, respectively. Both luminance and luminous efficiency increase gradually as Xe contents increases. With a high Xe partial pressure, the brightness and the luminance efficiency have a maximum value when He gas fraction is 10% for a standard AC PDP cell with Xe fraction of 4~30%.

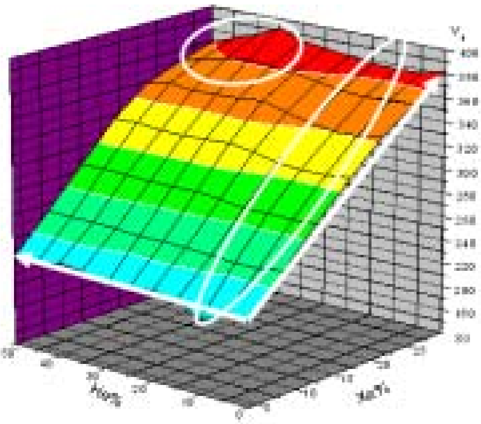

Fig. 2 Firing voltage characteristics by ternary gas mixture

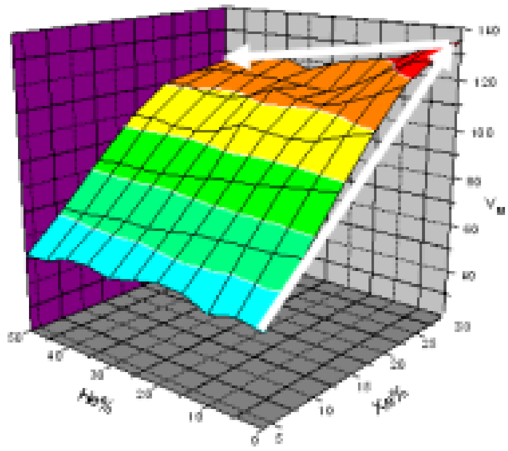

Fig. 3 Voltage margin characteristics by ternary gas mixture

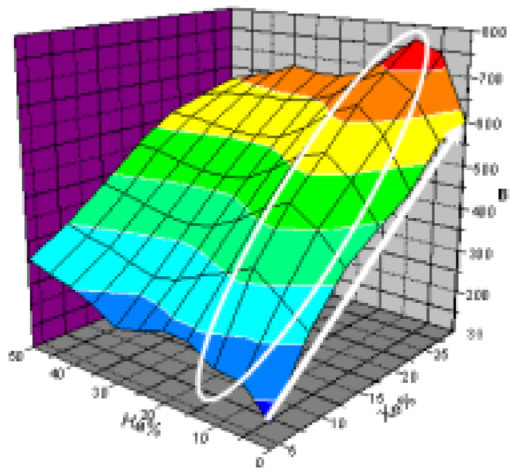

Fig. 4 Brightness characteristics (Cd/m^2)

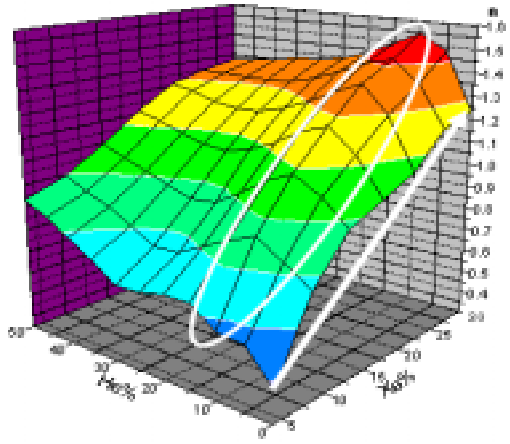

Fig. 5 The luminous efficiency characteristics by ternary gas mixture (X2 lm/W)

Figure 6 shows the discharge delay time according to He contents (5%~20%) when the address voltage increases from 60 V to 100 V with an increment of 10 V. As the partial pressure of He increases, the jitter time becomes longer.

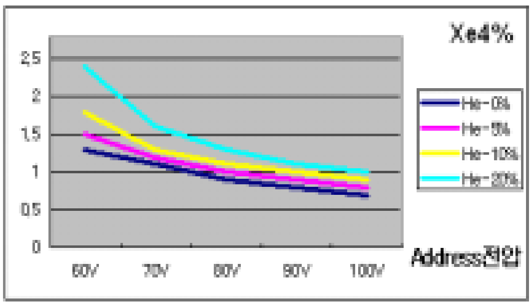

Fig. 6 Discharge delay time (jitter) versus address voltage for different He contents

3. Simulation

3.1 Analysis of Ionization Coefficients

Figure 7 shows the 1st Townsend coefficient (α) for different Xe partial pressure in Xe-Ne mixture. As Xe contents increases, the ionization coefficient for Xe increases while that for Ne decreases because the threshold energy for ionization of Xe (12.13 eV) is much lower than that for Ne (21.56 eV). Therefore, Xe ions are the dominant ion species in Xe-Ne mixture even with a small amount of Xe, e.g. 4%. Even though the total ionization coefficient increase for large Xe contents, the small amount of Ne ions results in the increase in the firing voltage because the secondary electron emission coefficient (SEEC) of Xe is much smaller than that of Ne [4]. The addition of He with the same Xe contents does not affect the ionization coefficient shown in Fig. 5.

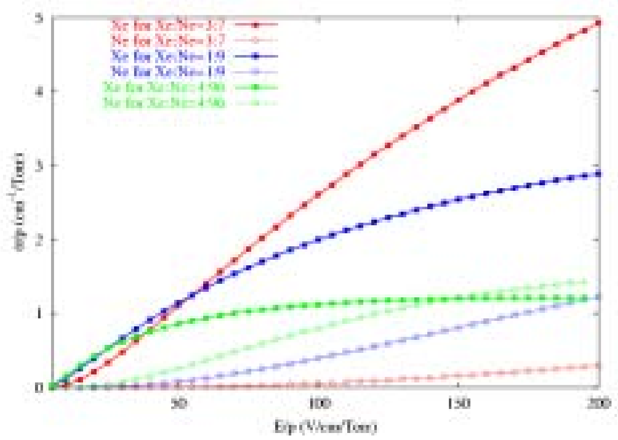

Fig. 5 The ionization coefficients of Xe and Ne for the change of Xe partial pressure in Xe-Ne mixture

3.2 Simulation Results

The two-dimensional fluid simulation consists of a set of continuity equations of electrons, ions, and excited species, Poisson's equation for the electric field, and momentum conservation equations with the drift-diffusion approximation [5]. The swarm parameters of electrons are calculated as a function of electric field over gas pressure (E/p) by solving zero-dimensional Boltzmann equation.

Figure 6 shows the comparison of density evolutions for high and low Xe contents with the same operation voltage of 280 V. When Xe:Ne=3:7, the density ratio of Ne ions to Xe ions is less than 5%, while it is 30% when Xe:Ne=4:96. As the SEEC of Ne^+ is much larger than that of Xe^+, Ne^+ is the dominant ions species. The Xe_2^+ and $NeXe^+$ ions also play important roles in the electron motions for long-time scale. The time averaged electron density in Fig. 6(a) is about 1.5 times larger than that in Fig. 6(b). The luminance and the luminance efficiency of the former are 2.5 times and 2 times larger than those of the latter, respectively. The tendency agrees well with the experimental results shown in Figs. 4 and 5.

If we add He to Ne-Xe gas mixture at the same sustain voltage, the charged particle density as well as the brightness increases slightly in low Xe contents. The increase of the created He ions is small, and thus the effect of He addition is minor for electron motions. However, He inclusion affects the ion motion of Ne ions by reducing the mobility. Moreover, the creation of Xe_2^* which emits UV of 173 nm increases with the increase of $Xe^*(^3P_2)$ generation by the collisions between Xe^{**} and He. Therefore, luminance increases.

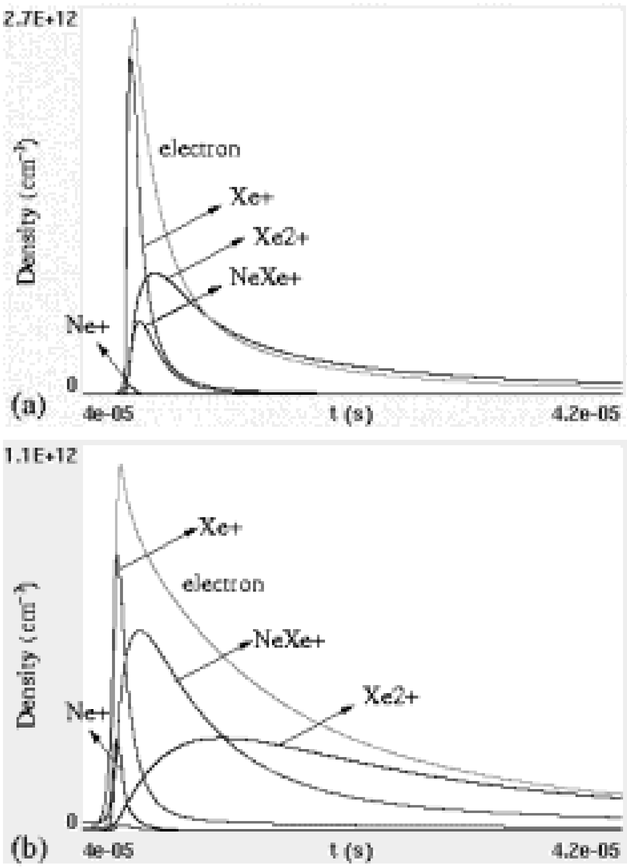

Fig. 5 The time evolution of the average densities of charged particles in sustain period for the cases of (a) Xe:Ne=3:7 and (b) Xe:Ne=4:96

When the partial pressure of Xe is high, Xe^+ is the most dominant ion species, and thus the effect of He inclusion on the change of ion mobility is not significant. However, the electron swarm parameters may be affected as the operation voltage and E/p becomes much higher than that of low Xe case. For this case, various atomic collisions also play important roles and the discharge characteristics become complicated.

4. Summary

We reported the experimental results for the optimization of the luminance efficiency in He-Ne-Xe gas mixture. With a low Xe partial pressure, the luminance efficiency increases with the amount of He with respect to Ne. With a high Xe partial pressure, however, the luminance efficiency has a maximum value when the ratio of He partial pressure to Ne is 10% for a standard AC PDP cell with Xe fraction of 10~30%. As a future work, a discharge roadmap is to be presented in order to explain the tendencies in firing and sustain voltages, discharge time lag, luminance, power loss, and luminance efficiency.

5. Acknowledgements

This work is supported by LG Electronics, Inc. and by Pusan National University Research Grant, 2004.

6. References

[1] K. Sakita *et al.*, SID 01 Digest, 1022 (2001) .

[2] J. Y. Yoo *et al.*, SID 01 Digest, 798 (2001).

[3] G. Oversluizen and T. Dekker, IMID'04 Digest, 55 (2004).

[4] H. S. Uhm *et al.*, Appl. Phys. Lett. **80**(5), 737 (2002).

[5] S. S. Yang *et al.*, IEEE Trans. Plasma Sci. 31(4), 596 (2003).