Plasma Display Panel With Ne+N_2 Gas-Mixture Discharges

Kyung Cheol Choi, Byung-Jong Baek, Heung-Sik Tae, *Member, IEEE*, and Hee Dong Park

***Abstract*—The discharge characteristics of Ne+N_2 gas-mixtures were investigated for possible use in an ac Plasma Display Panel. The firing voltage increased with an increase in the N_2 concentration. When using a near ultra violet excited phosphor, $(Ba,Sr)_2$ $SiO_4:Eu$, the luminous efficiency of Ne+10%N_2 gas-mixture discharges under 400 torr was about 20% better than when using the conventional phosphor. The UV intensity emitted from the gas discharges was found to increase with an increased N_2 concentration. Furthermore, the UV efficiency increased with an increase in the N_2 partial pressure at a low N_2 concentration, yet became saturated at a high N_2 concentration.**

***Index Terms*—N_2 gas-mixture, plasma display panel, ultraviolet.**

I. Introduction

ALTERNATING CURRENT (ac) plasma display panels (PDPs) are the most promising flat panel devices for use as a high definition TV screen. Conventionally, a plasma display panel utilizes a penning gas-mixture, such as Ne+Xe or He+Xe. As such, ultraviolet (UV) photons with 143 and 173 nm wavelengths emitted from Xe-excited species stimulate the photoluminescence phosphor to produce visible light. As regards the energy loss mechanism in a plasma display panel with a Xe gas-mixture discharge, only 10% of the discharge energy is used to produce UV photons, while 50% of the UV photon energy is unused when visible light is emitted from the photoluminescence phosphor [1]. Due to this inefficient lighting mechanism, a plasma display panel consumes a lot of power when used in TV and monitor applications. However, despite many efforts to reduce this high power consumption [2], [3], the efficiency of a plasma display panel is still low.

Accordingly, the current work investigated the use of a Ne+N_2 gas-mixture as the discharge gas in an ac plasma display panel. N_2 discharges emit UV photons within a range of 300$\sim$400 nm. When compared to the 147 and 173 nm from a Xe gas-mixture, the longer UV wavelength has advantages as a stimulation source for photoluminescence phosphor. The UV photon energy efficiency of an N_2 gas-mixture discharge is higher than that of a Xe gas-mixture discharge due to a smaller Stokes shift [4]–[6]. Here, the UV photon energy efficiency is defined as the energy of the visible photon divided by the energy of the UV photon. The electron heating rate of an Ne+N_2 gas-mixture is also greater than that of Xe+Ne [6]. As such, an N_2 gas-mixture has potential as a quantum cutting UV source. Therefore, the current study investigated the UV emission and discharge characteristics of an Ne+N_2 gas-mixture discharge.

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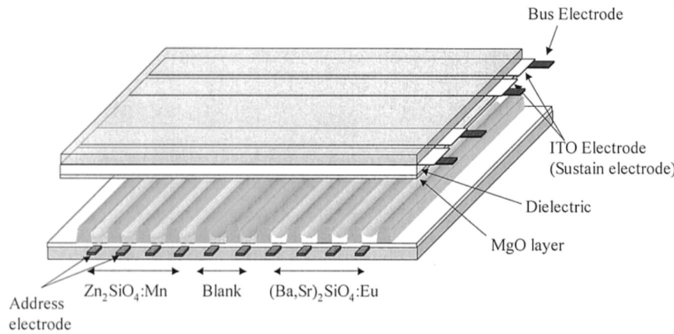
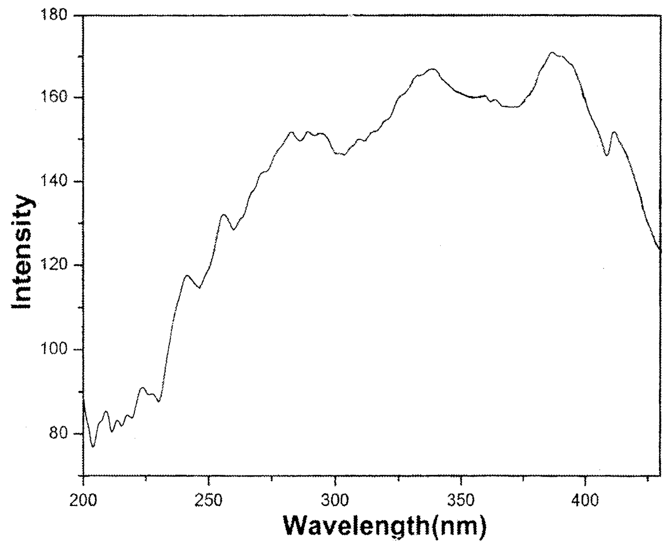


Fig. 1. The 4-in plasma display panel coated by two kinds of phosphor.

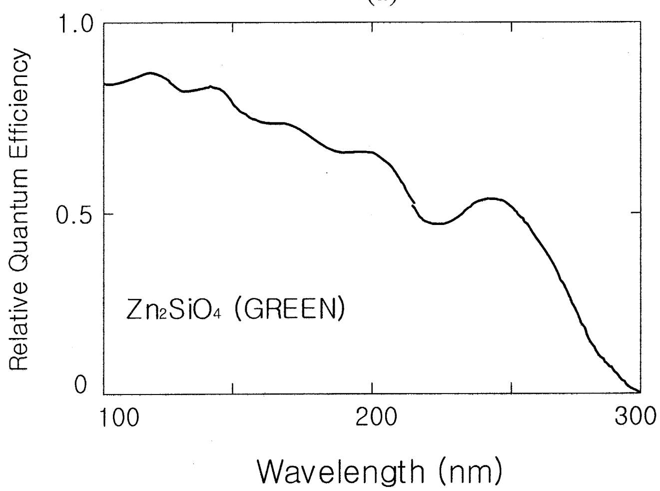
II. Experiment

Fig. 1 shows the 4-in test panel used in the current study. On the front plate, the sustain electrodes were made of Indium Tin Oxide (ITO) and patterned by photolithography. The distance between the two sustain electrodes was 80 μm, which was the surface discharge gap. The width of sustain electrode was 0.35 mm. The pitch of display pixel was 1.08 mm. The sustain electrodes were coated with bus electrodes using a screen-print method. Next, a 30 μm-thick transparent dielectric layer was applied, followed by the deposition of a 6800 Å thick MgO thin film using an electron-beam method.

On the rear plate, the barrier ribs were made using a sand-blasting method, while the phosphor layers were formed by a screen-printing process. The pitch of barrier rib was 0.36 mm. Two kinds of phosphor layer were fabricated on the rear plate, as shown in Fig. 1. One was conventional green phosphor, $Zn_2SiO_4:Mn$, and the other was $(Ba,Sr)_2SiO_4:Eu$ green phosphor, which is mainly excited by UV emissions within a range of 300$\sim$400 nm. Fig. 2(a) shows the excitation spectrum of the $(Ba,Sr)_2SiO_4:Eu$ phosphor. The excitation intensity exhibited a maximum value within a range of 330$\sim$380 nm, corresponding to the emission lines of the N_2 discharges. Fig. 2(b) shows the relative quantum efficiency of the conventional phosphor, $Zn_2SiO_4:Mn$. The green-emitting $(BaSr)_2SiO_4:Eu$ phosphor particles with a high luminescence intensity under near ultraviolet were prepared by ultrasonic spray pyrolysis. The apparatus used in the current study was an ultrasonic spray generator with six vibrators at 1.7 MHz. The



(a)

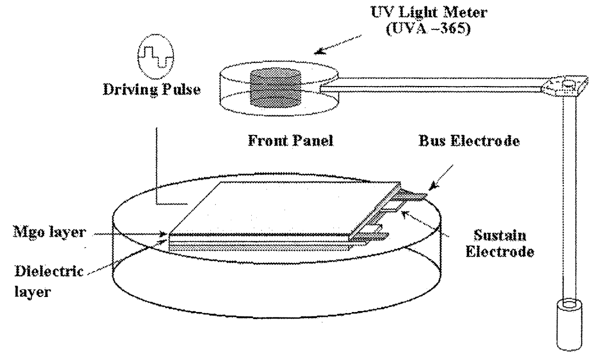


(b)

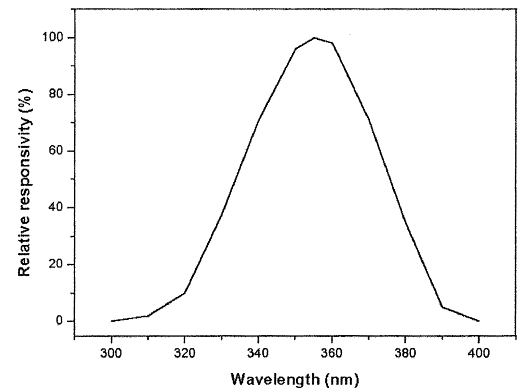
Fig. 2. (a) Excitation spectrum of $(Ba,Sr)_2SiO_4:Eu$ phosphor. (b) Relative quantum efficiency of the conventional phosphor, $Zn_2SiO_4:Mn$.

TABLE I
SPECIFICATIONS OF $Zn_2SiO_4:Mn$ and $(Ba,Sr)_2SiO_4:Eu$

Phosphor	Peak Wavelength [nm]	Particle size [μm]	CIE Color Coordinate
Zn_2SiO_4:Mn	525	3	(0.242, 0.708)
$(Br,Sr)_2SiO_4$:Eu	510	5	(0.201, 0.718)



(a)



(b)

Fig. 3. (a) Schematic diagram of UV detecting system when using UVA-365 sensor. (b) Spectral distribution of UVA-365 sensor.

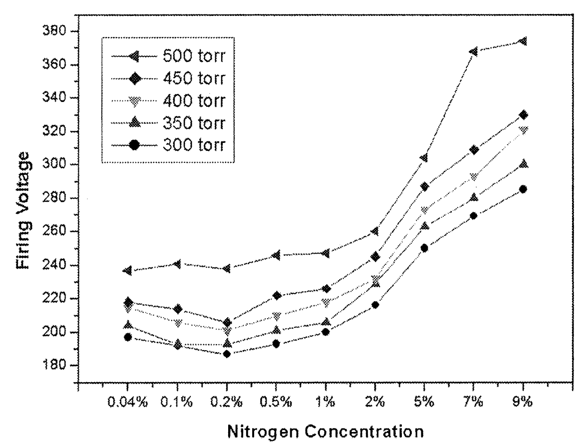


Fig. 4. Firing voltage as a function of gas pressure and N_2 concentration.

length and inside diameter of the quartz reactor was 1200 and 50 mm, respectively. The flow rate of air, used as the carrier gas, was 45 L/min and the residence time of the particles inside the reactor was 0.6 s. The particles prepared by spray pyrolysis were post-treated above 1200 °C under a reducing atmosphere. To improve the brightness of the phosphor particles, co-dopant and flux materials were introduced to the spray solution. The prepared phosphor particles displayed a high excitation intensity in the 300∼400 nm region and were applied to the plasma display panel operating under near ultraviolet. The phosphor particles prepared by spray pyrolysis exhibited a high luminescence intensity due to their high crystallinity and phase homogeneity. Table I shows the specifications of the newly synthesized phosphor compared with the one by the conventional process.

Usually, an ac PDP is adopting address display period separated (ADS) sub-field method [7]. During address period, the address pulse is applied to the address electrode and the scan

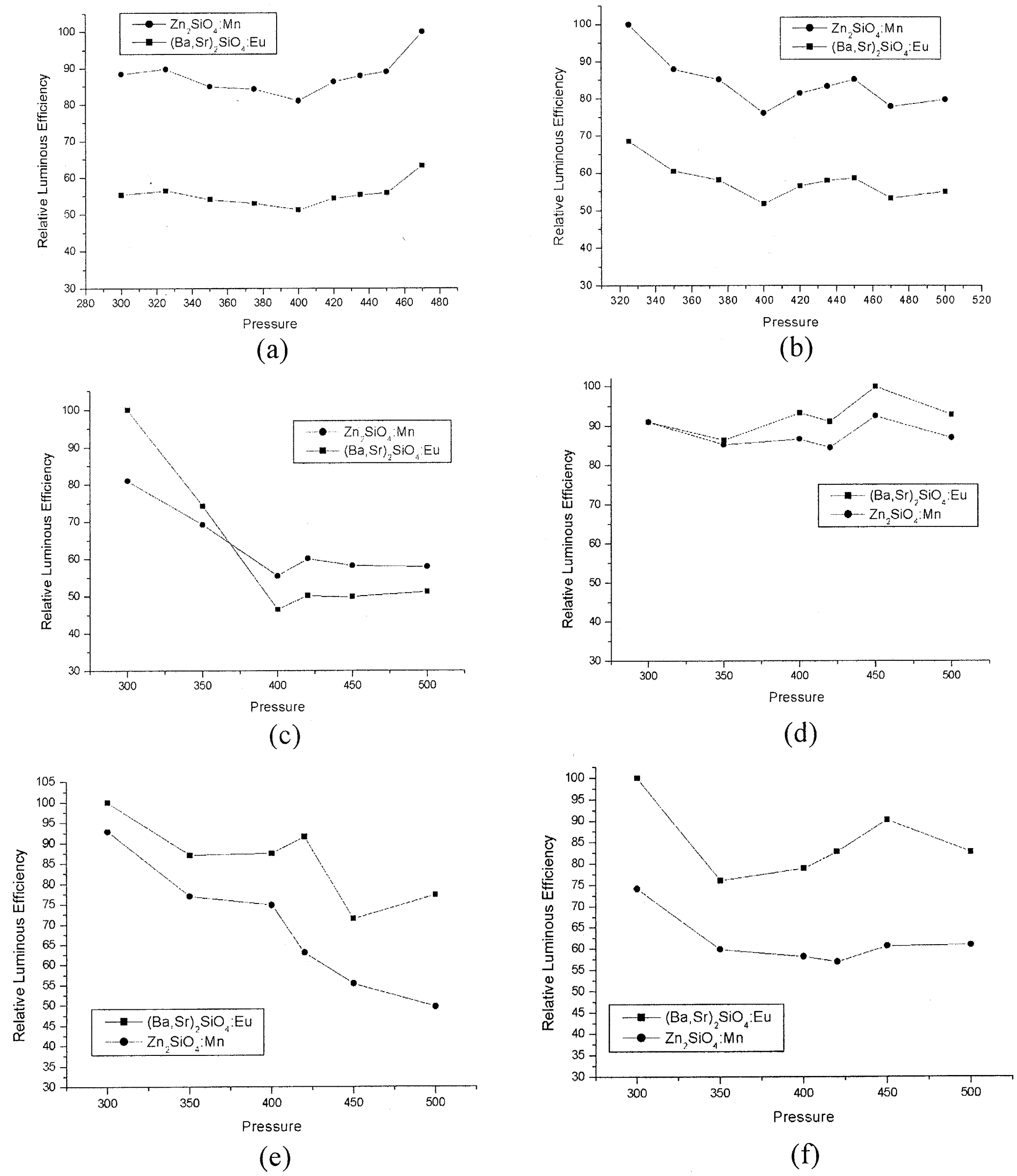


Fig. 5. Relative luminous efficiencies of Ne+N_2 gas-mixture discharges.

pulse is applied to one of the sustain electrodes as shown in the Fig. 1. During sustain period, the sustain pulses are applied to the sustain electrodes and the discharges are occurred between two sustain electrodes. One display pixel requires two sustain electrodes to maintain the surface discharge in an ac PDP. In this work, the discharge characteristics of Ne+N_2 gas-mixtures during sustain period were investigated.

To measure the ultraviolet intensity emitted from the Ne+N_2 gas-mixture discharge, the front plate and a UV lighter meter were used, as shown in Fig. 3(a). A UV measuring sensor, UVA-365, was introduced to detect photons with a 300∼400 nm wavelength emitted from the Ne+N_2 gas-mixture discharge. The front plate and UV detecting system were placed in a vacuum chamber, as shown in Fig. 3(a). Pulses with a 25 KHz frequency and 10 μs width were applied to the sustain electrode. The spectral distribution of the UVA-365 photo sensor is shown in Fig. 3(b).

III. Results and Discussion

The firing voltage between the two sustain electrodes was measured. Fig. 4 shows the firing voltage as a function of the gas pressure and N_2 concentration. The firing voltage increased with an increase in the gas pressure. At a low N_2 concentration, the firing voltage did not change much. However, the firing voltage started to increase when the concentration of N_2 increased because the collision cross section of N_2 gas is larger than that of Ne gas. There is less effect of N_2 gas on the firing voltage at a low N_2 concentration.

The relative luminous efficiencies of the Ne+N_2 gas-mixtures in the ac plasma display panel were investigated, as shown in Fig. 5. At a low N_2 concentration, such as 0.04% and 0.1% in Fig. 5(a) and (b), the firing voltage was acceptable, as shown in Fig. 4, however, it is likely that there were a few UV emissions within a range of 300∼400 nm from the Ne+N_2 gas-mixture

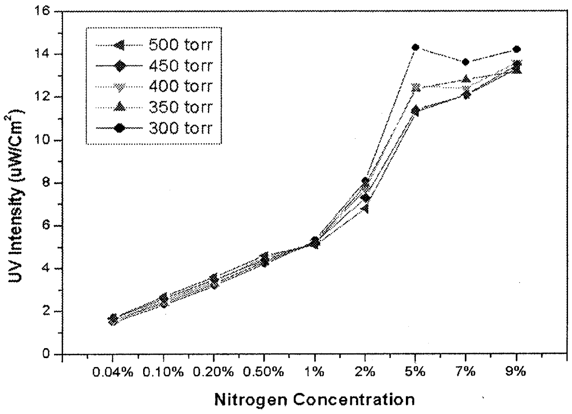


Fig. 6. UV intensity as a function of gas pressure and N_2 concentration.

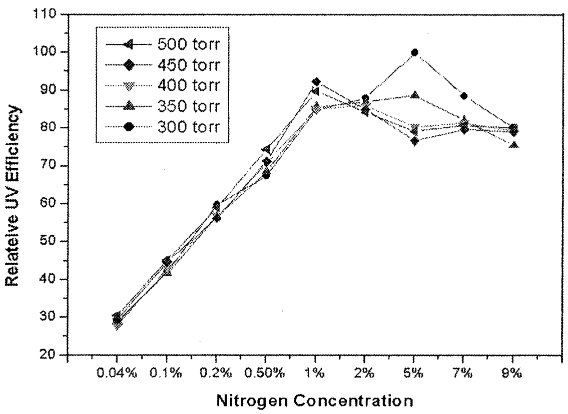


Fig. 7. Relative UV efficiency as a function of gas pressure and N_2 concentration.

discharges. With 0.04$\sim$0.1% N_2 concentration, the luminous efficiency of the 300$\sim$400 nm wavelength UV excited phosphor, $(Ba,Sr)_2SiO_4:Eu$, was lower than that of $Zn_2SiO_4:Mn$ phosphor. With a 1$\sim$5% N_2 concentration, as shown in Fig. 5(c) and (d), the luminous efficiency of $(Ba,Sr)_2SiO_4:Eu$ was approximately the same as that of $Zn_2SiO_4:Mn$. The 300$\sim$400 nm wavelength UV emission increased as the N_2 concentration increased. With a high N_2 concentration, there was a relatively high UV emission from the Ne+N_2 gas-mixture discharges and the luminous efficiency of $(Ba,Sr)_2SiO_4:Eu$ was much higher than that of $Zn_2SiO_4:Mn$, as shown in Fig. 5(e) and (f). Numerical values of vertical axes of 6 plots in Fig. 5 are not all same. Fig. 5 shows the relative luminous efficiency of Ne+N_2 gas-mixture discharges for the comparison between the proposed panel and the conventional panel at each N_2 concentration.

Fig. 6 shows the UV intensity measured by the UVA-365 photo sensor. The UV output relative to the N_2 concentration increased linearly until 1%, increased steeply until 5%, and then became saturated.

Finally, the UV efficiency of a Ne+N_2 gas-mixture discharge was investigated as shown in Fig. 7. The UV efficiency was obtain from the UV output divided by the power applied to the sustain electrodes. The UV efficiency increased linearly with an increase in the N_2 concentration until 1%. Under a gas pressure of 450 torr, the UV efficiency exhibited a maximum value at a 1% N_2 concentration, and no further increase at N_2 concentrations of 5 to 9%.

IV. Conclusion

Gases emitting a longer wavelength UV compared to the 147 nm and 173 nm from a Xe gas-mixture can be used for high luminous efficiency in a plasma display panel. The current study investigated the discharge characteristics of a Ne+N_2 gas-mixture and the application of 300 $\sim$400 nm excited photoluminescence phosphor, $(Ba,Sr)_2SiO_4:Eu$, in an ac plasma display panel. A higher N_2 concentration resulted in a higher firing voltage. Furthermore, as the N_2 concentration increased, the luminous efficiency of the $(Ba,Sr)_2SiO_4:Eu$ phosphor became higher than that of the conventional $Zn_2SiO_4:Mn$ phosphor. The absolute values of luminance and luminous efficiency of the proposed panel are similar with those of conventional panel. However, there are lots of possibilities of improving the characteristics of the proposed panel because the phosphor stimulated by longer wavelength ultraviolet and the pixel structure are not optimized for the commercial ac PDP.

References

[1] J. S. Kim and K. W. Whang, "Technology trend of high luminous efficiency," *Proc. Korean Inform. Display Soc.*, vol. 2, no. 4, pp. 13–18, 2001.
[2] Y. Kanazawa *et al.*, "High resolution interlaced addressing for plasma display," in *Proc. SID'99*, 1999, pp. 154–157.
[3] K. Amemiya *et al.*, "High luminous efficiency and high definition coplanar ac PDP with T-shaped electrodes," in *Proc. IDW'98*, 1998, pp. 531–534.
[4] W. T. Lee *et al.*, "Excimer gas discharge characteristics for color ac-PDPs," in *SID'00 Dig.*, 2000, pp. 730–733.
[5] H. Hatanaka *et al.*, "Luminous Efficiency evaluation of XeI excimer for ac-PDP," in *Proc. IDW'00*, 2000, pp. 615–618.
[6] D. Hayashi, G. Heusler, and M. Klein, "Nitrogen gas-mixtures for ultra violet radiation in PDPs," in *Proc. IDW'01*, 2001, pp. 929–931.
[7] K. Yoshikwa *et al.*, "A full color ac plasma display with 256 gray scale," in *Proc. Int. Display Res. Conf.*, 1992, pp. 605–608.

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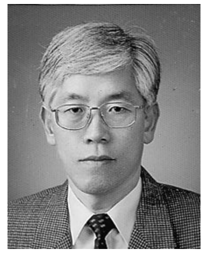

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