Effects of Neon Plasma Emission on Optical Properties of Phosphor Layers in Surface-Type Alternate Current Plasma Display Panel

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Abstract

This study uses neon and xenon gas mixture discharges to determine the effects of the neon plasma emission on the characteristics of visible emission from the stimulation of the red, green, blue(RGB) phosphor layers in a surface-type alternate current plasma display panel(AC PDP). With a mixture of less than 2% xenon to neon, it is found that the luminance changes in the visible emission of the phosphor layers are similar to those of the neon plasma emission. In the range of xenon mix ratio from 2 to 5%, the luminance of the red, green, blue(RGB) phosphor layers decreases with a decrease in the neon plasma emission intensity. However, with a mixture of above 5% xenon to neon, the luminance of the red, green, blue(RGB) phosphor layers increases regardless of a decrease in the neon plasma emission intensity. Furthermore, the color purity of the red, green, blue(RGB) phosphor layers improve as the neon plasma emission intensity decreases. Accordingly, it is concluded that the optical properties of the phosphor layers, including color purity and luminance, depend on the neon plasma discharge emission as well as the visible emission from the stimulation of the phosphor layers.

Introduction

With the recent rapid progress in information technology, the demand for the development of the various flat panel display devices that can express information and image efficiently, has significantly intensified[1,2]. PDP is one of the most promising flat panel devices for the large area(>40inch) full color wall hanging High Definition Televisions(HDTVs)[3]. For the successful realization of commercial full color HDTVs, further improvements are needed in the PDP device, especially in luminance, luminous efficiency and color purity. In recent years, a lot of research has focused on vacuum ultraviolet(VUV) emission for the stimulation of the red, green, blue(RGB) phosphor layers in an AC PDP device using a xenon-based gas mixture to improve the ultraviolet and visible generation capability of PDPs[4,5]. There have also been attempts to develop new phosphor materials suitable for improving the luminance and color purity of phosphor layers in an AC PDP. Since the PDP is a display device that uses a gas discharge, the effects of the visible emission from the discharge itself on the luminance and color purity of an AC PDP are unavoidable. Accordingly, to improve the color purity and brightness required for the realization of commercial full color PDP devices it is necessary to investigate the visible emission characteristics of the plasma discharge within an AC PDP cell. Nonetheless, research on visible emission characteristics, including the effects of the plasma emission, has often been neglected. In this work, changes in the luminance and color purity of the visible emission from the neon plasma in a surface discharge AC PDP cell without phosphor layers were investigated using various Ne-Xe gas mixtures. In particular, the effects of the neon plasma emission on the optical characteristics of visible emission from the stimulation of the red, green, blue(RGB) phosphor layers in the AC PDP cell were investigated.

Experimental

Fig.1 shows the structure of the surface-type AC PDP test cell utilized in this study. The test cell consists of front glass plate and rear glass plate. On the front glass plate, two parallel-conducting discharge electrodes were made of silver paste by using screen printing and then fired at a temperature of 570°C. The width of discharge electrode and the gap between the two discharge electrodes were 300μm and 100μm, respectively. The dielectric layer on top of the discharge electrodes was prepared using screen printing with two different dielectric pastes(Noritake, NP-7972C and NP-7973C), and then fired at a temperature of 540°C, to give a thickness of 20μm. An MgO layer with a thickness of 3000Å, which has a high secondary electron emission coefficient thereby enhancing discharge and low sputtering yield to protect the dielectric layer, was deposited on the dielectric layer by sputtering. The phosphor layers on the rear glass plate contained $(Y,Gd)BO_3$:Eu(Red), Zn_2SiO_4:Mn(Green) and $BaMgAl_{10}O_{17}$:Eu (Blue), made using screen printing and fired at a temperature of 510°C, respectively. The distance between the

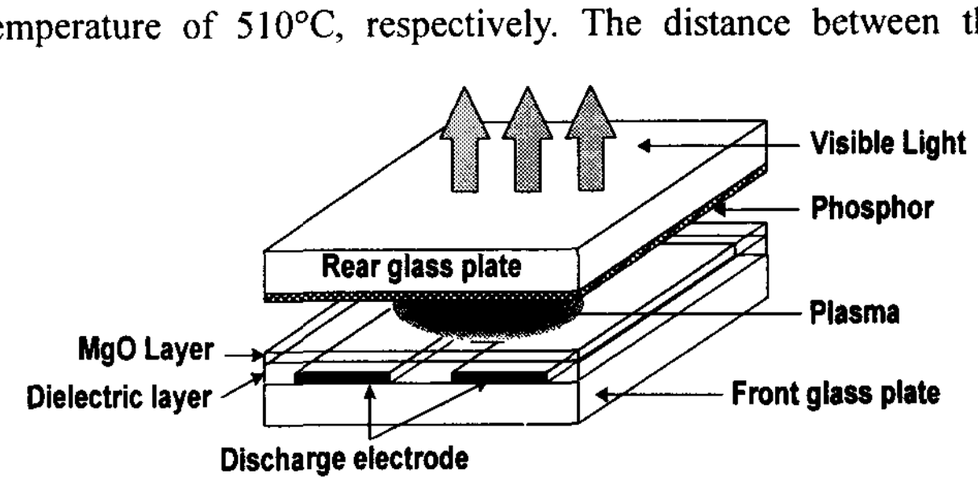

Fig.1 The structure of surface type AC PDP test cell

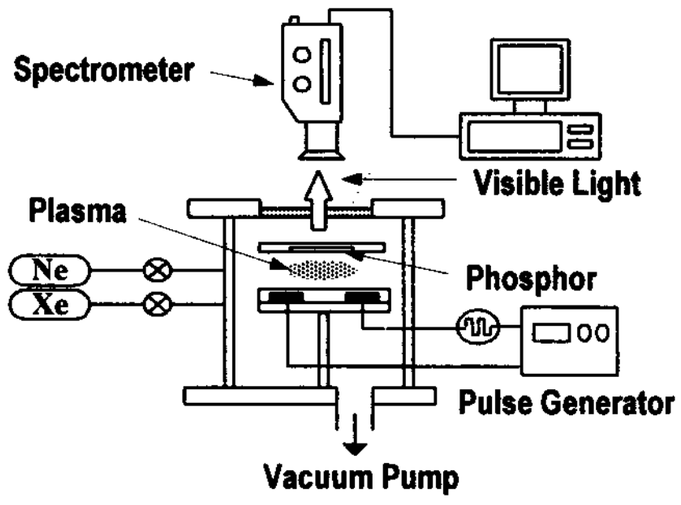

Fig.2 Schematic diagram of optical measurement system from AC PDP test cell

discharge electrode and the phosphor layer was about 250μm.

Fig.2 shows a schematic diagram of the optical measurement system of the visible emission produced in an AC PDP cell. The plasma in the AC PDP test cell with the Ne-Xe gas discharge was generated under a pressure of 200Torr by applying sustain pulses with a 30KHz frequency and 300 voltage. The VUV and visible light were both emitted from this plasma discharge plus visible light was also emitted through the phosphor layer. The phosphor layer was only excited by the VUV produced from Xe or Ne excitation during the plasma discharge, whereas visible light was produced from the VUV stimulation of the phosphor layer. The visible light from the plasma discharge was also produced from the Ne excitation during the plasma discharge. This visible light from the Ne plasma discharge then influenced the visible light through the phosphor layer. With a range of 380~760nm, the spectrometer shown in Fig.2 measured the luminance and color purity of the visible light emitted from the AC PDP test cell both with and without phosphor layers.

Result and Discussion

Fig. 3 illustrates the spectrum of the visible light emitted from the Ne plasma discharge without the phosphor layer as a function of Xe mix ratio. With a 0% Xe mix ratio, the Ne atoms excited by electron collisions with only Ne decay to metastable state emitting spectral line of visible light as shown in (1).

$$Ne + e \rightarrow Ne^* + e,\ Ne^* \rightarrow Ne^m + h\gamma\ (\text{Visible light}) \qquad (1)$$

In (1), Ne^* represents an excited Ne atom, and Ne^m represents a metastable state of Ne atom. Table 1 lists the details of spectrum peaks due to the Ne plasma emission from the PDP test cell[6]. With a Xe mixture below 2%, despite an increase of the Xe mix ratio, the spectrum intensity of the visible light emitted from the Ne plasma discharge was found to be almost unchangeable. With a Xe mixture above 2%, the intensity of the Ne spectrum peaks decreases with an increase of the Xe gas in the Ne-Xe gas mixture, implying that the luminance of the plasma discharge itself decreases as shown in Fig.5(d).

Fig.4 shows the spectrum of the visible light emitted through the red, green, and blue phosphor layers from the AC PDP cell. The spectrum peaks of Fig.4 consist of the

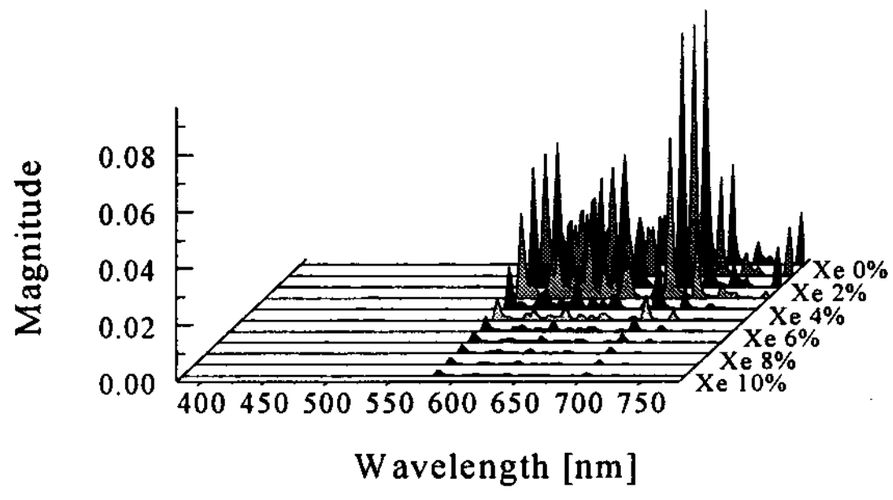

Fig.3 Spectrum of visible emission from PDP test without phosphor layer

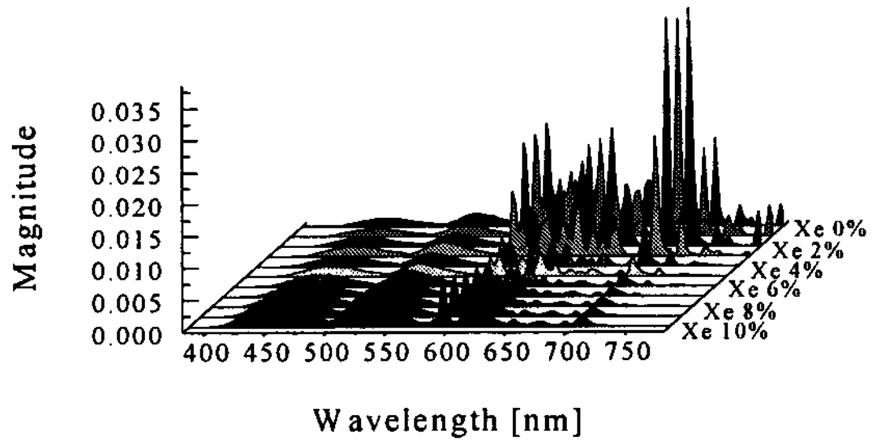

Fig.4 Spectrum of visible emission from PDP test with phosphor layer

(unit : [nm])

Spectrum peaks from Ne plasma and transition						
585.2 ($2p_1$-$1s_2$)	659.8 ($2p_2$-$1s_2$)	607.4 ($2p_3$-$1s_4$)	667.8 ($2p_4$-$1s_2$)	594.4 ($2p_4$-$1s_5$)	626.6 ($2p_5$-$1s_3$)	629.9 ($2p_6$-$1s_2$)
614.3 ($2p_6$-$1s_6$)	650.6 ($2p_8$-$1s_4$)	640.2 ($2p_9$-$1s_5$)	743.8 ($2p_{10}$-$1s_3$)	724.5 ($2p_{10}$-$1s_4$)	703.2 ($2p_{10}$-$1s_5$)	
Spectrum peaks from the blue phosphor layer		Spectrum peaks from the green phosphor layer		Spectrum peaks from the red phosphor layer		
400 ~ 500		500 ~ 600		592	610	620

Table.1 Wavelength of spectrum peaks from Ne plasma discharge and phosphor layers

$1s_j$ ($j = 2 \rightarrow 5$) levels represent the first excited 3s configuration in Ne

$2p_j$ ($j = 1 \rightarrow 10$) levels represent the next higher energy 3p group in Ne

superposition of the Ne plasma emission and the visible emission from the stimulation of the red, green, and blue phosphors, as listed in Table1. With a 0% Xe mixture, the emission spectra consist of the Ne plasma emission and the visible emission of the red, green, and blue phosphor layers excited by the VUV(74.4nm) produced from the radiative transitions of the excited Ne atom as shown in (2)

$$Ne + e \rightarrow Ne^* + e,\quad Ne^* \rightarrow Ne + h\gamma\ (74.4\text{nm}) \qquad (2)$$

With a Xe mixture below 2%, despite an increase of the Xe mix ratio, the spectrum intensity of the visible light emitted from both the Ne plasma discharge and the red, green, and blue phosphor layers was found to be almost unchangeable. With an increase of the Xe mix ratio, the excitation probability of Ne atoms are lowered due to a decrease in the electron energy caused by the

collisions between the electrons and the Xe atoms. However, electrons are also created by a penning ionization that can generate the Xe ions through the collision between the Xe atom and the Ne atom of the metastable state as shown in (3)[7]. S.Y.Lee has reported that a penning ionization well occurred at 0.01~2% Ar mix ratio in the case of the Ne+Ar discharge[7]. In our experimental result with the Ne+Xe discharge, it was observed that no changes in the spectrum intensity were made at below 2% Xe mix ratio.

$$Ne^m + Xe \rightarrow Xe^+ + Ne + e \quad (3)$$

With a Xe mixture from 2 to 5%, the spectrum intensity of both the Ne emission and the visible emission of the red, green, and blue phosphor layers decreases monotonically as the Xe mix ratio increases. This diminution of the Ne spectrum intensity with an increased Xe mix ratio is presumed to be due to a decrease in the electron temperature caused by the frequent collisions with Xe atoms that have a higher collision frequency than Ne atoms. With a Xe mixture from 2 to 5%, the phosphor layers are mainly excited by VUV(74.4nm) due to the transitions to the ground state of the excited Ne atoms, however, the phosphor layers are only partially excited by the VUV(147nm) due to a small amount of a Xe atomic emission. Accordingly, the decrease in the red, green, and blue emission spectrum peaks with an increase in the Xe mix ratio up to 5% is related to a reduction of the VUV(74.4nm) intensity produced from the transition to the ground state of the excited Ne atoms. This reduction of the VUV(74.4nm) intensity is due to a decrease in the electron energy caused by the collision between the electrons and the Xe atoms. With an increase of Xe mix ratio greater than 5%, the spectrum intensity of the Ne plasma is gradually lowered by a reduction in the excitation probability of the Ne atom due to the decreased electron energy. Nonetheless, as shown in Fig.4, the intensity of red, green, and blue emission spectrum peaks increases. This increase of the visible emission intensity is due to the increased VUV of 173nm, which is produced from the radiative dissociation of the Xe dimer as follows[8,9].

$$Xe + Xe^* + Ne \rightarrow Xe_2^* + Ne \quad (4)$$

$$Xe_2^* \rightarrow 2Xe + h\gamma\,(173mm) \quad (5)$$

In (4), Xe^* represents an excited Xe atom and Xe_2^* represents an excited dimer molecule.

Fig.5 shows the changes in the luminance of the visible light emitted through the green(a), red(b), and blue(c) phosphor layers, and from the Ne plasma discharge(d) without phosphor layer with an increase in the Xe mix ratio. As shown in Fig.5, the luminance of both Ne plasma discharge and phosphor layers are almost unchangeable as the Xe mix ratio increase up to about 2%. This phenomenon can be explained by a creation of electrons due to a penning ionization with an increase of Xe mix ratio below 2% as explained in Fig.4. In the range of Xe mix ratio from 2 to 5%, the luminance of both Ne plasma discharge and phosphor layers decreases monotonically a reduction in the electron temperature

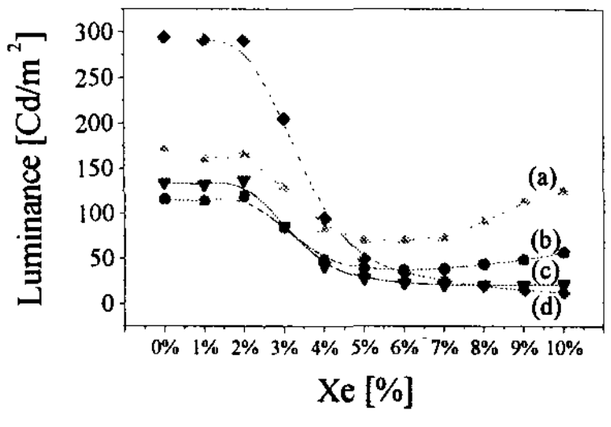

Fig.5 Luminance of visible emission from PDP test cell
(a) Green (b) Red (c) Blue (d) Neon plasma

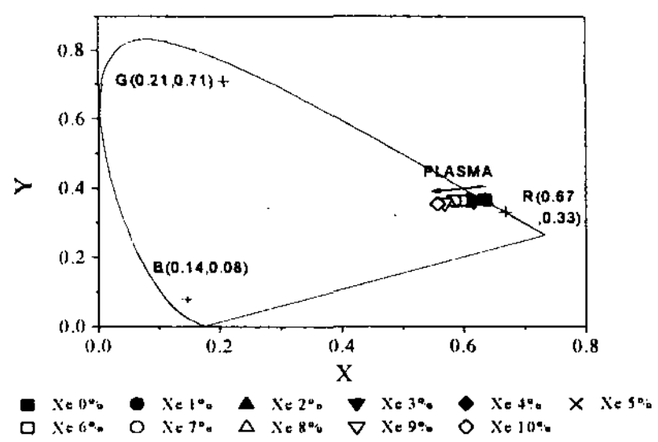

Fig.6 Chromaticity diagram[1931] of neon plasma emission from PDP test cell

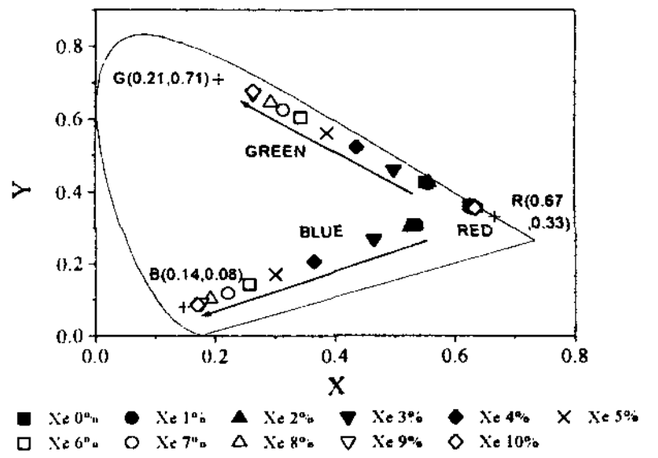

Fig.7 Chromaticity diagram[1931] of visible emission of phohphor layer from PDP test cell

by the collisions with the Xe atoms. In contrast, with a Xe mix ratio greater than 5%, the luminance of the red, green phosphor layers except the blue phosphor layer increases regardless of a decrease in the Ne plasma emission intensity. This improved luminance is caused by the increase in the VUV emission produced from the radiative dissociation of the Xe dimer as the Xe mix ratio increases above 5%.

Fig.6 shows the changes in the color coordinate[1931] of the Ne plasma emission obtained under the same condition as in Fig.3 and Fig.4. As shown in Fig.6, the value of x and y coordinate decreases with an increase in the Xe mix ratio. However, the color coordinates of the Ne plasma emission mainly belong to the red color region, implying that the visible light from the Ne plasma discharge can deteriorate the color purity of both the green phosphor and blue phosphor layer.

Fig.7 shows the changes in the color coordinate[1931] of the phosphor layers under the same as in Fig.6. The value of x and y coordinate shifts to a great extent to the NTSC region in the case

of visible light emitted from the AC PDP cell with green, and blue phosphor layers except red phosphor layer, indicating that the color purity of the green, and blue phosphor layers improves much with an increased Xe mix ratio. This improvement of the color purity of the AC PDP cell is thought to be due to the reduction of luminance of the Ne plasma discharge.

Conclusion

The effects of the neon plasma emission on the optical properties such as color purity and luminance of phosphor layers in a surface-type AC PDP, are examined by using neon and xenon gas mixture discharges. It is found that the luminance of a surface-type AC PDP cell depend on the neon plasma discharge emission as well as the visible emission from the stimulation of the phosphor layers. With a mixture of less than 2% xenon to neon, the luminance changes in the visible emission of the phosphor layers are similar to those of the neon plasma emission. With a Xe mix ratio from 2 to 5%, the luminance of the red, green, and blue phosphor layers decreases with a decrease in the neon plasma emission intensity. In contrast, at above 5%, the luminance of the red, green, and blue phosphor layers increases regardless of a decrease in the neon plasma emission intensity. In particular, the visible emission from the neon plasma discharge has a strong influence on the color purity of AC PDP cell. Furthermore the color purity of the green, and blue phosphor layers improves much as the neon plasma emission intensity decreases.

Acknowledge

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