

Effects of plasma emission on optical properties of phosphor layers in surface-type alternate current plasma display panel

Sang-Hun Jang and Heung-Sik Tae^{a)}

School of Electronic and Electrical Engineering, Kyungpook National University, 1370 Sankyuk-Dong, Buk-gu, 702-701, Taegu, Korea

Jeong-Hae Lee

School of Electronic and Electrical Engineering, Hong-Ik University, Seoul, Korea

Kyung Cheol Choi

Department of Electronics Engineering, Sejong University, Seoul, Korea

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This study uses helium and xenon gas mixture discharges to determine the effects of helium plasma emission on the characteristics of the visible emission from the stimulation of the red, green, and blue (RGB) phosphor layers in a surface-type alternate current plasma display panel. With a mixture of less than 2% xenon to helium, it was found that the luminance of the RGB phosphor layers decreases with a decrease in the helium plasma emission intensity. However, with a mixture of above 2% xenon to helium, the luminance of the RGB phosphor layers increases regardless of a decrease in the helium plasma emission intensity. Furthermore, the color purity of the RGB phosphor layers improves as the helium plasma emission intensity decreases. Accordingly, it can be concluded that the optical properties of the phosphor layers, including color purity and luminance, depend on the helium plasma discharge emission as well as the visible emission from the stimulation of the phosphor layers. © 2000 American Institute of Physics. [S0021-8979(00)01105-1]

I. INTRODUCTION

With the recent progress in information technology, the demand for the development of various flat panel display devices that can express information and images efficiently has significantly intensified.^{1,2} Plasma display panel (PDP) is one of the most promising flat panel devices for large area (>40 in.) full color wall hanging high definition television (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 UV (VUV) emission for the stimulation of the red, green, and blue (RGB) phosphor layers in an ac PDP device using a xenon-based gas mixture to improve the UV and visible generation capability of the PDPs.^{4,5} There have also been attempts to develop new phosphor materials suitable for improving the luminance and color purity of the 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 helium plasma in a surface

discharge ac PDP cell without phosphor layers were investigated using various He–Xe gas mixtures. In particular, the effects of the helium plasma emission on the optical characteristics of the visible emission from the stimulation of the RGB phosphor layers in the ac PDP cell were investigated.

II. EXPERIMENT

Figure 1(a) shows the structure of the surface-type ac PDP test cell utilized in this study. The test cell consisted of front and rear glass plates. On the front plate, two parallel-conducting discharge electrodes were made of silver paste using screen printing and then fired at a temperature of 570 °C. The width of the discharge electrode and the gap between the two discharge electrodes were 300 and 100 μm, 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 20 μm. A MgO layer with a thickness of 3000 Å, which has a high secondary electron emission coefficient thereby enhancing the discharge and low sputtering yield to protect the dielectric layer,⁶ was deposited on the dielectric layer by sputtering. The phosphor layers on the rear glass plate contained (Y,Gd)BO₃:Eu(Red), Zn₂SiO₄:Mn(Green), and BaMgAl₁₀O₁₇:Eu(Blue) made using screen printing and fired at a temperature of 510 °C. The distance between the discharge electrode and the phosphor layer was about 250 μm. Figure 1(b) shows a schematic diagram of the optical measurement system of the visible emission produced in an ac PDP cell. The plasma of the ac PDP test cell with the He–Xe gas discharge was generated under a pressure of 200

^{a)}Electronic mail: hstae@ee.kyungpook.ac.kr

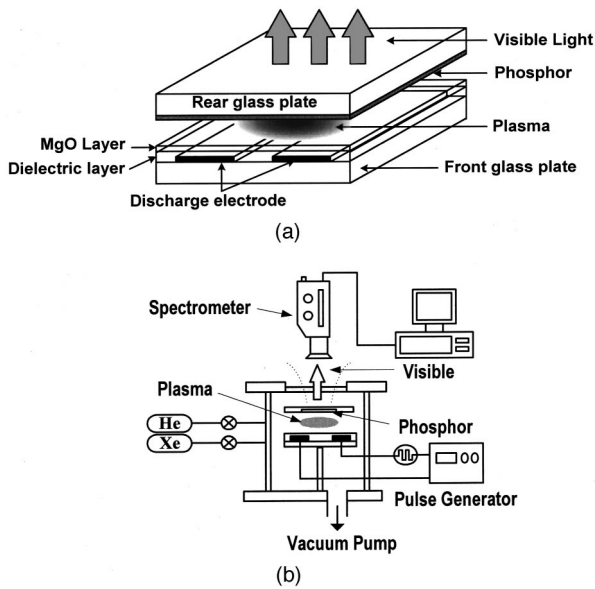


FIG. 1. Schematic diagram of optical measurement system for visible emission from ac PDP test cell: (a) surface-type ac PDP test cell and (b) optical measurement system.

Torr by applying sustain pulses with a 30 kHz frequency and 300 voltage. VUV (147 or 173 nm) 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 the Xe or He 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 He excitation during the plasma discharge. The visible light from the He plasma discharge then influenced the visible light through the phosphor layer.

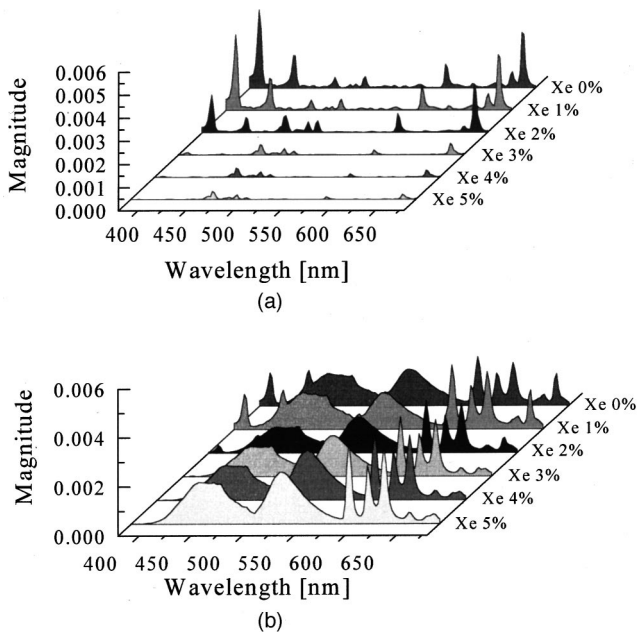


FIG. 2. Spectrum peaks of visible emission from ac PDP test cell: (a) spectrum of visible emission from PDP test cell without phosphor and (b) spectrum of visible emission from PDP test with phosphor layer.

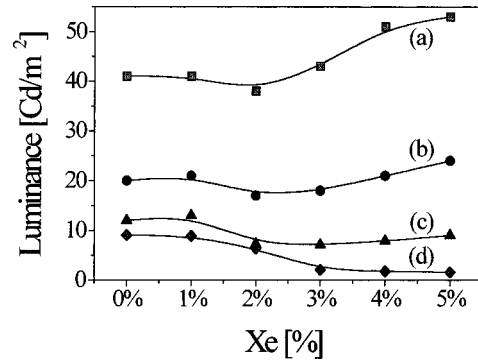


FIG. 3. Luminance of visible emission from PDP test cell: (a) green, (b) red, (c) blue, and (d) helium plasma.

Within a range of 350–750 nm, the spectrometer shown in Fig. 1(b) measured the luminance and color purity of the visible light emitted from the ac PDP test cell both with and without the phosphor layers.

III. RESULTS AND DISCUSSION

Figure 2(a) illustrates the spectrum of the visible light emitted from the He plasma discharge without the phosphor layer as a function of the Xe mix ratio. With a 0% Xe mix ratio, the He atoms excited by electron collisions with only He atoms decayed to lower energy states, and the He spectrum lines were measured at 388.8, 426, 470, 501.5, 587.5, 654, and 667.8 nm, respectively. The intensity of the He spectrum peaks decreased with an increase of the Xe gas in the He–Xe gas mixture, implying that the luminance of the plasma discharge itself decreases as shown in Fig. 3(d). This diminution of the He spectrum intensity with an increased Xe mix ratio is presumed to be due to a decrease in the electron energy caused by collisions with Xe atoms that have a higher collision frequency than He atoms. Table I lists the details of the spectrum peaks due to the He discharge emitted from the PDP test cell. Figure 2(b) shows the spectrum of visible light emitted through the RGB phosphor layers from the ac PDP cell. The spectrum peaks of Fig. 2(b) consist of the superposition of the He plasma emission and the visible emission from the stimulation of the red, green, and blue phosphor layers, as listed in Table I. With a 0% Xe mixture,

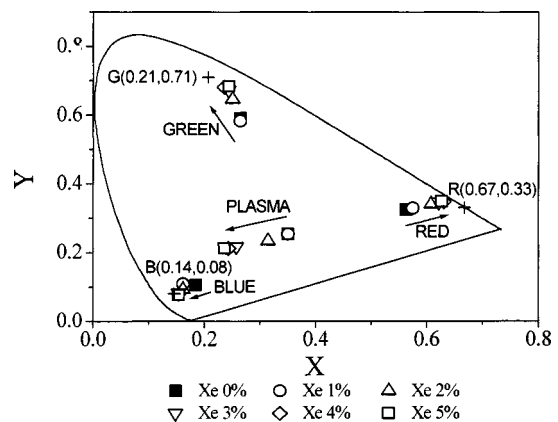
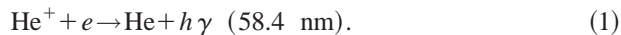


FIG. 4. Chromaticity diagram [1931] of visible emission from PDP test cell.

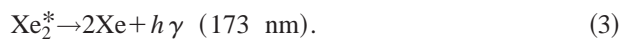
TABLE I. Wavelength of spectrum peaks from He plasma discharge and phosphor layers.

Spectrum peaks (nm) from He plasma						
388.8	426	470	501.5	587.5	654	667.8
Spectrum peaks from blue phosphor layer (nm)	Spectrum peaks from green phosphor layer (nm)		Spectrum peaks from red phosphor layer (nm)			
400–500	500–600		592	610	620	

the emission spectra consisted of the He plasma emission and the visible emission of the RGB phosphor layers excited by the VUV (58.4 nm) produced from the electron-He ion recombination as follows:⁷



With a Xe mixture below 2%, the phosphor layers were mainly excited by the VUV (58.4 nm) due to the electron-He ion recombination, however, the phosphor layers were only partially excited by the VUV (147 nm) due to a small amount of a Xe atomic emission. Accordingly, the decrease in the RGB emission spectrum peaks with an increase in the Xe mix ratio up to 2% is related to a reduction of the VUV (58.5 nm) intensity produced from the electron-He ion recombination. This reduction of the VUV (58.4 nm) intensity is due to a decrease in the electron energy caused by the collision between the electrons and the Xe atoms. With a Xe mixture above 2%, the VUV formation during the He–Xe discharge is governed by the dimer formation and subsequent radiative dissociation of Xe as follows:⁸



In Eq. (2), Xe* represents an excited Xe atom and Xe₂* represents an excited dimer molecule. As the Xe mix ratio increases above 2%, an excited Xe dimer is formed through the three-body process as shown in Eq. (2). The excited Xe dimer then produces a VUV of 173 nm through the radiative dissociation shown in Eq. (3). With an increased Xe mix ratio greater than 2%, the excitation probability of the He atoms during the He–Xe discharge is reduced due to a decrease in the electron energy. Nonetheless, as shown in Fig. 2(b), the intensity of the RGB emission spectrum peaks increased. This increase of the visible emission intensity is due to the increased VUV of 173 nm, which is produced from the radiative dissociation of the Xe dimer.

Figure 3 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 He plasma discharge (d) without a phosphore layer with an increase in the Xe mix ratio. As shown in Fig. 3(d), the luminance of the He plasma discharge decreased monotonically as the Xe mix ratio increased. In contrast, the luminance of the visible emission

through the RGB phosphor layers decreased slightly until the Xe mix ratio increased to about 2%. However, as the Xe mix ratio increased above 2% the luminance increased monotonically as shown in Figs. 3(a), 3(b), and 3(c). In other words, when the Xe mix ratio was less than 2%, the decrease in He plasma emission intensity resulted in a reduction of the luminance of the RGB phosphor layers. Yet, when the Xe mix ratio was greater than 2%, the luminance of the RGB phosphor layers increased regardless of a decrease in the He 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 2%. Figure 4 shows the changes in the color coordinate [1931] obtained under the same conditions as in Figs. 2 and 3. With an increase of Xe gas in the He–Xe mixture, the value of the *x* and *y* coordinate decreased in the case of the He plasma emission without phosphor layers. However, the value of the *x* and *y* coordinate shifted to the NTSC region in the case of the visible light emitted from the ac PDP cell with RGB phosphor layers, indicating that the color purity of the RGB phosphor layers improved with an increased Xe mix ratio. This improvement of the color purity of the ac PDP cell is thought to be due to a reduction of the luminance of the He plasma discharge.

IV. CONCLUSIONS

The effects of the helium plasma emission on the optical properties of the phosphor layers in a surface-type ac PDP, including color purity and luminance, were examined using helium and xenon gas mixture discharges. It was found that the luminance of a surface-type ac PDP cell depends on the helium 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 helium, the luminance of the RGB phosphor layers decreased with a decrease in the helium plasma emission intensity. However, above 2%, the luminance of the RGB phosphor layers increased regardless of a decrease in the helium plasma emission intensity. In particular, the visible emission from the helium plasma discharge had a strong influence on the color purity of the ac PDP cell. Furthermore, the color purity of the RGB phosphor layers improved as the helium plasma emission intensity decreased.

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