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# Microdischarge using priming particles for reducing neon emission in AC plasma display panel with Ne-Xe-He gas mixture

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Abstract

This study uses neon, xenon, and helium gas mixture microdischarge to determine the effects of priming particles on the neon emission characteristics in an alternate current plasma display panel (AC PDP). The infrared (823 nm) and neon emission (585 nm) intensities are measured and compared in the blue cells in the case of new discharge with priming particles or conventional discharge without priming particles, respectively. It is found that the priming particles can produce a plasma discharge effectively even under the weak electric field condition, thereby resulting in reducing the neon emission intensity remarkably without sacrificing the IR emission intensity. As a result, it is found that the Ne emission intensity is reduced by about 46.4 % but the blue visible emission intensity is increased by about 15.2 % when compared with the conventional discharge without priming particles.

**Key Words :** priming particles, Ne emission, AC plasma display panel, Ne-Xe-He gas mixture

## 1. Introduction

Plasma display panel (PDP) is a display device that expresses information as a full color image by using the plasma produced in microdischarge cells. The full color images on a PDP are displayed based on a combination of the red, green, and blue colors, which are emitted from stimulation of the red, green, and blue phosphor layers excited by the vacuum ultraviolet (VUV) during a Ne-Xe-He plasma discharge in the microdischarge cells. A Ne emission, i.e., an orange light with a wavelength of 585 nm, is inevitably generated from the Ne-Xe-He plasma discharge producing the 147 nm or 173 nm VUV emission[1]. This Ne emission is considered as a main culprit in deteriorating the color purity of the PDP device, because the Ne emission worsens the purity of the blue and green colors emitted from stimulation of the blue and green phosphor layers. Various methods have been suggested for minimizing the intensive Ne emission based on the use of optical filter[2] or the optimization of the gas chemistry[3].

In a conventional Ne-Xe-He plasma discharge, an orange light of 585 nm is emitted under the high electric field intensity condition because the energy state of Ne is relatively high[4,5]. Therefore, as the plasma discharge intensity decreases or increases, the corresponding Ne emission intensity also weakens or strengthens accordingly. This implies that an attempt to reduce the Ne emission may lead to the decrease in the luminance in the conventional plasma discharge from the PDP cells. Consequently, weakening the Ne emission intensity without reducing the luminance of the visible emission from the PDP cells would appear to be very difficult. In order to solve this problem, the Xe species for the VUV emission need to be excited more efficiently under the weak electric field condition which can reduce the Ne emission intensity. In this sense, to reduce the Ne emission intensity without sacrificing the VUV intensity, one option is to utilize the priming particles such as space charges, because the presence of the priming particles can produce the efficient microdischarge even under the weak electric field condition[6,7]. In general, it is well-known that the priming particles such as the space charges and metastable atoms can contribute to lowering the firing voltage and reducing the delay of the discharge initiation, because they participate in producing the plasma discharge as seed particles necessary for breakdown[6,7]. So far, however, much attention has not been paid to the Ne reduction techniques using the

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priming effect.

In this paper, the priming particles are used to reduce the Ne emission intensity without causing any loss in luminance in the 7-inch AC PDP test panel with a Ne-Xe-He gas mixture. The priming particles are produced by using the auxiliary voltage applied to the address electrode. The effects of the priming particles on the IR and Ne emission characteristics are examined by measuring the time-resolved spectra of the infrared (823 nm) and neon emission (585 nm) from the Ne-Xe-He plasma in the blue cells.

## 2. Experiment

Figs. 1(a) and (b) show the optical measurement system used to measure the IR (823 nm) and Ne emission (585 nm) from a single pixel comprised of the red, green, and blue cells in the 7-inch AC PDP test panel employed in the current research. The dimensions of the single pixel in Fig. 1(a) are about 1260 μm in width, 1260 μm in length, and about 130 μm in height, respectively. The widths of the two sustain electrodes X and Y are 320 μm, respectively, and the gap distance between the two sustain electrodes X and Y is about 60 μm. The width of an address electrode Z is about 100 μm.

The discharge volumes for the red, green, and blue cells are separated by the symmetric striped barrier ribs with a width varying from 60 μm at top to 80 μm at bottom and a height of 130 μm. Accordingly, the micro-discharge volume for producing the plasma discharge per subpixel is approximately 0.89 $mm^3$ because the plasma is produced mainly between the two sustain electrodes.

The plasma in the 7-inch AC PDP test panel with the Ne-Xe (4 %)-He gas mixture is generated under the pressure of 400 Torr by alternately applying the sustain voltages $V_{sx}$ and $V_{sy}$ with an amplitude of 170 V at a frequency of 50 kHz to the sustain electrodes X and Y, as shown in Fig. 2. In the conventional driving method, no voltage is applied to the address electrode Z during a sustain-period, so that the priming particles do not exist in this case. In this work, however, the auxiliary voltage $V_z$ is simultaneously applied to the address electrode Z slightly prior to the application of the sustain voltage $V_{sx}$ and $V_{sy}$ during a sustain-period so as to produce the priming particles at the beginning of the plasma discharge, as shown in Fig. 2.

The auxiliary voltage $V_z$ has two abrupt voltage transitions per sustain voltage. The first abrupt transition from −90 V to 0 V contributes to producing the priming particles by triggering the wall charges, whereas the

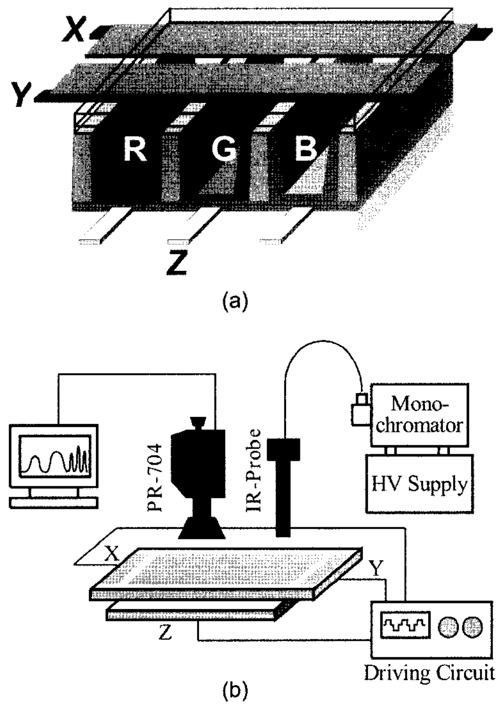


Fig. 1. Schematic diagram of single pixel (a) comprising red, green, and blue cells in 7-inch AC PDP test panel and optical measurement system (b) for measuring IR (823 nm) and Ne emission (585 nm) from test panel.

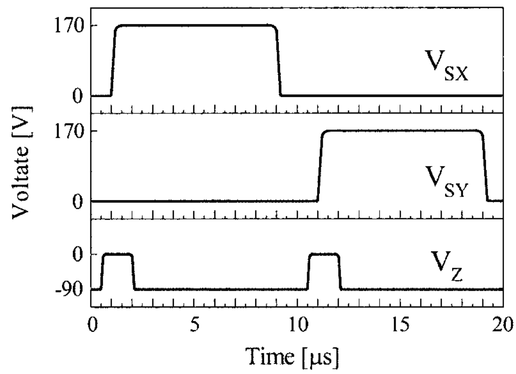


Fig. 2. Voltage waveforms applied to three electrodes X, Y, and Z for producing priming particles employed in this research.

second abrupt transition from 0 V to –90 V contributes to accumulating more wall charges from the space charges within the cell. Accordingly, the auxiliary voltage $V_z$ applied to the address electrode Z plays a role in producing the priming particles in the current study. The physical description of the production of priming particles with a variation of the auxiliary voltage is discussed in[8].

However, the detailed physical mechanism of the production of priming particles will need to be analyzed clearly through the further study based on the conversion phenomena between the space charges and the wall charges within the microdischarge cells. This paper focuses mainly on the effects of the priming particles on the discharge characteristics such as the reduction of the Ne emission.

The time variations in the peak intensities of infrared (IR) of 823 nm and Ne emission of 585 nm are measured by using a monochromator and Photo-Multiplier-Tube (PMT). The CIE chromaticity coordinates and emission spectra of the red, green, and blue lights are also measured by using a PR-704 spectrometer.

## 3. Results and Discussion

Fig. 3 illustrates the time-resolved emission spectra of the IR (823 nm) and Ne (585 nm) measured from the blue cells of the 7-inch AC PDP test panel when employing either conventional discharge without priming particles (a) or new discharge with priming particles (b), respectively. These priming particles are caused by the X-Z discharge. Since IR of 823 nm is a precursor for excited Xe atoms generating a VUV of 173 nm, the discharge characteristics and VUV emission characteristics can be indirectly analyzed from the IR waveforms[9]. Table 1 shows the various reactions for the Ne-Xe species. The energy necessary for an ionization and excitation in Ne species or for an excitation in Xe species is listed in Table 1.

In the case of the conventional discharge without priming particles produced by only applying the sustain voltage with no address voltage, the IR and Ne emission waveforms exhibit a single peak, as shown in the Fig. 3(a). These waveforms are often shown in the typical Xe-Ne plasma discharge. The strong electric field is required to emit the Ne visible emission in the typical Xe-Ne plasma discharge, because most reactions such

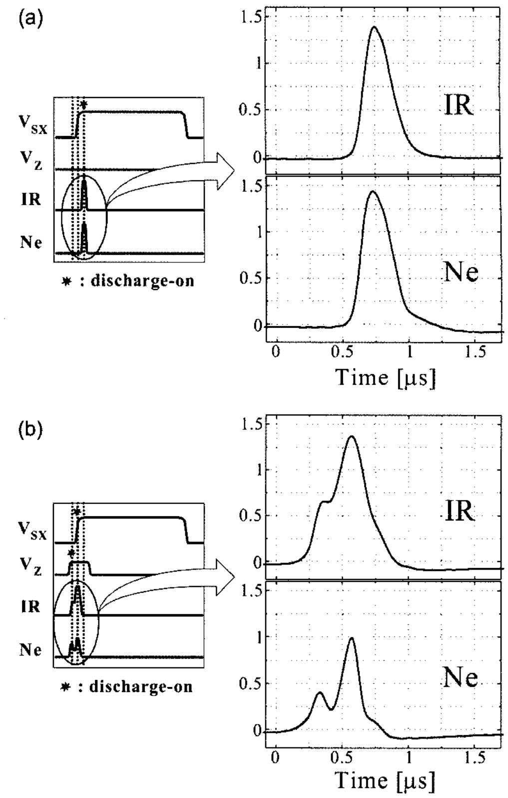


Fig. 3. Time-resolved emission spectra of IR (823 nm) and Ne (585 nm) measured from blue cells of 7-inch AC PDP test panel (a): Plasma discharge is produced once under strong electric field condition as shown at position of * in conventional discharge without priming particles (b): Plasma discharge is produced twice under weak electric field condition as shown at position of * in new discharge with priming particles.

Table 1. Reactions in Ne-Xe species.

| |
|---|
| Neon emission |
| Ne(2p53p)(18.97) → Ne(2p53s) + hν(585 nm) |
| Direct ionization |
| $e^- + Ne \rightarrow Ne^+(21.6\ eV) + 2e^-$ |
| Excitation |
| $e^- + Ne \rightarrow Nem^*(16.6\ eV) + e^-$ |
| $e^- + Ne \rightarrow Ner^*(16.7\ eV) + e^-$ |
| $e^- + Ne \rightarrow Ne^{**}(18.7\ eV) + e^-$ |
| Neutral kinetics |
| Xem*(8.32 eV) + Xe + Ne → Xe2* + Ne |
| Spontaneous emission |
| Xe2* → 2Xe + hν(173 nm) |
| Xer*(8.44 eV) → Xe + hν(147 nm) |

as an ionization and excitation for the Ne atoms require the higher energy levels at least greater than 16.6 eV, as shown in Table 1[4,5]. Moreover, the Ne emission of 585 nm is generated from the excited state of Ne (2p53p) and its excitation energy from the ground state is 18.97 eV[10]. Accordingly, in this typical discharge, a weak electric field should be applied to the microdischarge cells to weaken the Ne emission intensity, but the corresponding VUV intensity also tends to become simultaneously weak in proportion to the reduced Ne emission intensity. Consequently, the color purity does not change merely based on a reduced Ne emission intensity.

In contrast, in the case of the new discharge with priming particles produced by applying the sustain voltage with the auxiliary voltage, the IR and Ne emission waveforms are found to have double peaks, as illustrated in the measured waveforms of Fig. 2(b). As shown in the magnified shapes of the Fig. 3(b), the double peaks of the IR and Ne emissions are shifted to the left, when compared with the single peak of Fig. 3(a), which indicates that the plasma within the PDP cell is produced under the weak electric field condition. The first small peaks in Fig. 3(b) are produced during the X-Z discharge under the weak electric field caused by the auxiliary voltage change from –90 V to 0 V so as to create the priming particles. The electric field is still low even at the time of generation of the second peaks produced by the X-Y discharge (Fig. 3(b)), since the sustain voltage $V_{sx}$ does not reach the maximum level. This phenomenon is due to the priming particles produced by the auxiliary voltage. A large amount of priming particles, such as electrons and ions, required to fire the main discharge are introduced near the gap between the sustain electrodes X and Y, thereby contributing to the attenuation of both the firing voltage and the time lag for firing. As a result, the sufficient number of priming particles induced by the auxiliary voltage $V_z$ slightly prior to the application of the sustain voltage $V_{sx}$ help the subsequent main discharge to be produced efficiently under the lower electric field intensity. As mentioned before, a stronger electric field is needed to produce a Ne emission because the energy state of Ne is relatively high. However, in the current case, the main discharge is effectively produced in the relatively lower electric field due to the sufficiency of priming particles, which results in reducing the Ne emission intensity considerably, as shown in the double peaks of the Ne emission waveform in Fig. 3(b).

As shown in Table 1, the VUV of 147 nm or 173 nm is generated from the resonant state $X_{er}^*$ (8.44 eV) and the metastable state $X_{em}^*$ (8.32 eV)[11]. The energy levels of these species are relatively low. Thus, in the case of the presence of many priming particles, a weak electric field can contribute to enhancing the excitation of Ne-Xe-He gas instead of the ionization of Ne-Xe-He. Consequently, if the priming particles exist at the beginning of the plasma discharge, the IR emission can be promoted even under the weak electric field condition. As illustrated in the double peaks of the IR emission of Fig. 3(b), the first peak is lower than the second peak, but the second peak is almost the same intensity as that in the conventional plasma discharge without priming particles of Fig. 3(a). The first low peak of the IR emission is observed from the discharge induced by the auxiliary voltage so as to produce the priming particles, whereas the second high peak of the IR emission is observed from the main discharge produced by the weak electric field due to the presence of the priming particles. This experimental result of Fig. 3(b) confirms that if the priming particles exist at the initiation of plasma discharge, the priming particles can assist not only in promoting the IR emission but also in reducing the Ne emission intensity considerably.

Fig. 4 shows the visible emission spectra measured from the blue cell in order to investigate the effects of

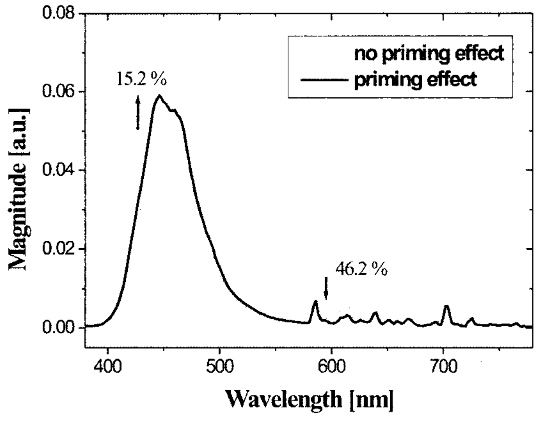


Fig. 4. Variations of visible emission spectra from blue cell in case of either conventional discharge with no priming particles or new discharge with priming particles.

priming particles on both the blue light emitted from stimulation of the blue phosphor layer and the Ne emission produced from the Ne-Xe-He plasma discharge. The blue emission peak increases by about 15.2 % in the case of the plasma discharge with the priming particles relative to the plasma discharge with no priming particles. This increase in the blue emission from the phosphor layer stimulated by the VUV in the blue cell states that the IR emission is much promoted even under the weak electric field condition due to the priming particles, as mentioned before. On the other hand, the corresponding Ne emission intensity from the discharge decreases by about 46.2 %, verifying that the Ne emission from the Ne-Xe-He plasma discharge in the blue cell is reduced considerably due to the priming particles. In this case, the total luminance from the blue cell increases slightly from 385 $cd/m^2$ to 390 $cd/m^2$ (not shown here). In addition, the wall voltage is reduced by the weak discharge between X and Z, but the dynamic margin is almost same because the wall charge transform into the priming particles[12].

As shown in the CIE (1931) chromaticity coordinates of Fig. 5, the color chromaticity coordinates x and y of the blue emission from the blue cell are varied remarkably from (0.179, 0.102) to (0.164, 0.093) due to the priming particles. From the viewpoint of color purity, the decrease in both x and y coordinates in the blue light from the blue cell means the improvement of the blue color purity. As a result, it is expected that the microdischarge using the priming particles can contribute to enhancing the color image quality of an AC PDP.

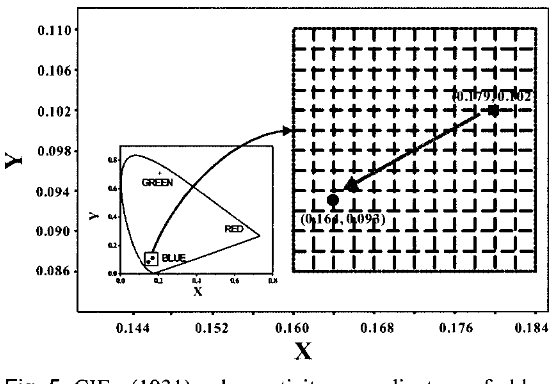


Fig. 5. CIE (1931) chromaticity coordinates of blue emission from blue cell in case of either conventional discharge with priming particles or new discharge with priming particles.

## 4. Conclusions

In this paper, the effects of priming particles on the neon emission characteristics were examined in the blue microdischarge cell of the AC plasma display panel with Ne-Xe (4 %)-He gas mixture. The emission intensities for the IR of 823 nm and Ne of 585 nm were measured and compared in the blue cells in the case of either new discharge with priming particles or conventional discharge without priming particles, respectively. Our experimental results confirm that as the priming particles assist in producing the plasma discharge effectively even under the weak electric field condition, they can reduce the Ne emission intensity remarkably and simultaneously promote the IR emission.

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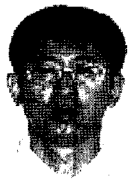

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