Emission Characteristics of Flat Fluorescent Lamp for LCD Backlight Using Inert Gas Mixture

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Keyword :Xe Lamp, Back Light Unit (BLU), Flat Fluorescent Lamp (FFL), Screen-printing.

Abstract

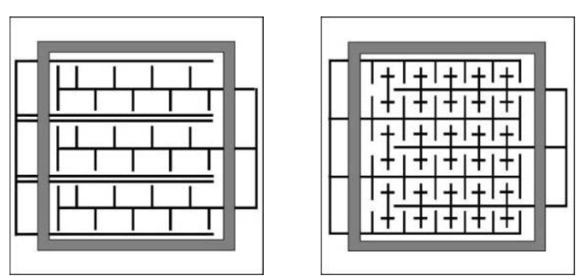
In this study, flat fluorescent lamps (FFLs) having surface discharge structures was fabricated by screen printing technique and were studied using spectra-radiometer and square pulse power supply. Two types of FFLs having different shapes of electrodes (cross-type and line-type structure) were compared with variation of discharge shape and mixed gas ratio.

1. Introduction

Recently, there have been many researches going on about flat panel display like PDP, LCD, FED, and so on. Among them, since LCD is non-emissive type display, it needs a backlight unit (BLU) for lighting, leading to high power consumption. Nowadays, cold cathode fluorescent lamp (CCFL) is generally used as a backlight.[1] However CCFL contains small amount of mercury, which is very harmful to the human body and natural environment as well. Therefore, there are some moves in EU on restricting import of products containing hazardous materials such as RoHS and WEEE.[2,3] Eventually the development of new eco-backlight systems is quite essential. Xe plasma FFL is one of eco-lamps.[4] However, the optimization of the Xe plasma FFL system has not been accomplished yet such as an efficient plasma lamp design, luminance, optimum gas mixture composition, luminous efficacy, etc. In this study, two types of Xe plasma FFL having different electrode geometry (cross type and line type structure) was assembled and characterized with variation of gas mixture.

2. Experiments

For assembling FFL panel, silver electrodes, a white back dielectric layer, and a phosphor layer were screen-printed on the rear glass and fired at 550, 450, and 570℃, respectively in sequence. On front glass, another phosphor layer was printed and fired. Both front and rear glasses were sealed at 450℃ and then pumped out under the pressure of 10^{-3} torr at 150℃ for 60 min to completely remove organic residues. Xe-Ar-He-Ne inert mixture gases were injected after vacuuming 10^{-6} torr for efficient plasma discharge. Two types of FFL were designed as shown in Fig. 1. Line type FFL in Fig. 1(a) is a simple and basic structure as a reference. Cross type FFL in Fig. 1(b) is a modified structure of line type FFL to intentionally enlarge the plasma space in a cell, inducing larger vacuum ultraviolet and leading to higher luminance. The luminance characteristics of the two types of FFL were compared and characterized with variation of Xe-Ar-He-Ne gas composition using spectra-radiometer (Minolta, Cs-1000A) and square pulse power supply (Ftlab, PDS-4000).



(a) (b)

Fig. 1. FFL Structure of (a) line type and (b) cross type.

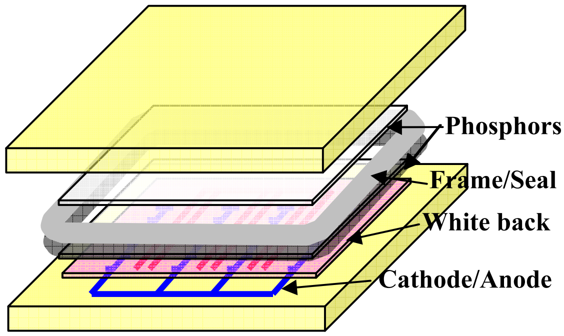


Fig. 2. Structure of coplanar electrode FFL.

3. Results and discussion

When plasma was generated by electrons excited from an applied voltage, its property is affected by gas species having inherent electron energy. Generally, inherent electron energy is proportional to ionization energy, which is inversely proportional to ionization cross-section. The ionization and electron energy of xenon is the smallest among theses noble gases and the ionization cross-section is the largest (Table 1).

Table 1. Ionization energy and atomic weight for the noble gases

Gas	He	Ne	Ar	Xe
Ionization Energy(eV)	24.5	21.5	15.7	12.1
Atomic weight	4.0	20.1	39.9	131.2

That means that Xe plasma is confined to smaller area than other He, Ne, or Ar plasmas due to more electron collisions at short distance. Figure 3 shows the glow discharge of noble gases. Xe gas panel showed more concentrated plasma around the electrodes with irregular distribution (Fig. 3(a)). However, Ar gas panel formed more uniform plasma around electrodes with regular pattern due to its smaller ionization cross-section than Xe (Fig. 3(b)). On the other hand, He and Ne plasmas were evenly distributed to whole area of panels without much concentration of plasma around electrodes (Fig. 3(c) and 3(d)).

In all ternary gas systems, gas mixtures having less than 20% of Xe showed significantly low luminance. Over 20% of Xe in ternary gas system, its luminance appeared to be almost close to pure

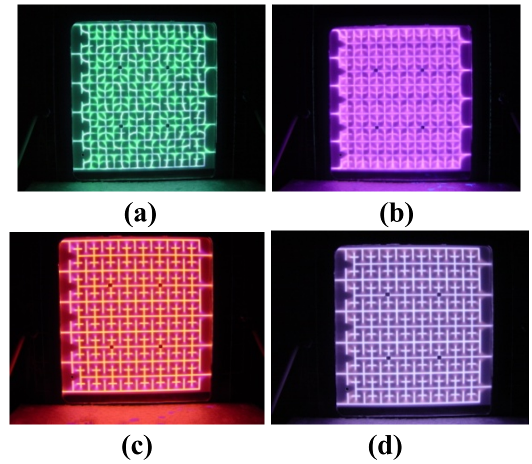


Fig. 3. Plasma images of (a) Xe, (b) Ar, (c) He, and (d) Ne gases using cross type electrode.

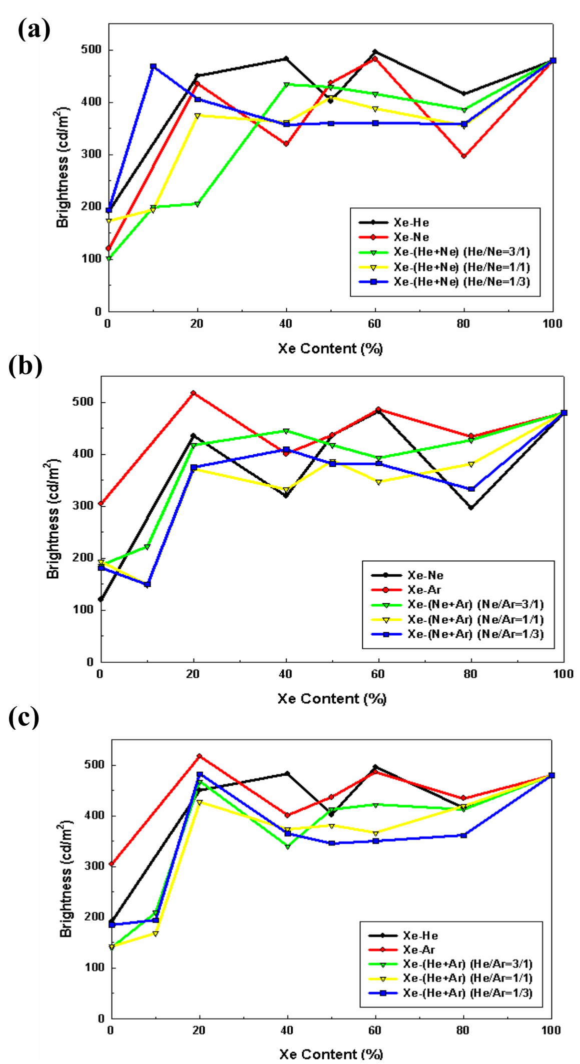


Fig. 4. Luminance of FFLs using (a) Xe-He-Ne, (b) Xe-Ne-Ar, and (c) Xe-He-Ar gas system.

Xe luminance although there are some fluctuations in luminance with Xe content. Among ternary gas systems, Xe-He-Ar system gave the least fluctuation in luminance with Xe content (Fig. 4(c)). In binary gas systems, the decreasing order of luminance was Xe-Ar, Xe-He, and Xe-Ne. In our study, 20%Xe-80%Ar gas system showed the highest brightness. Ar and Xe gases play a role in possibly more stable plasma and better luminance, respectively.

The efficiency (η) and the power consumption (P) is defined as below,

$$\eta = \frac{\pi A L}{P}\ [\mathrm{lm/W}]$$

where π is constant, A is the area, L is the luminance, and P is the power consumption.

$$P = 2f \int_0^{T/2} V_s(t)[I_{on}(t) - I_{off}(t)]dt\ [\mathrm{W}]$$

where V_s is the sustain voltage, I is the electric current, and f is the frequency.[5-8] The cross type FFL generated more glow discharge than the line-type FFL owing to higher number of branches in a cell. Accordingly, the cross type FFL emits more vacuum ultra violet (VUV), which excites phosphors more, consequently inducing higher luminance as shown in Fig. 5. Despite the higher luminance of cross type FFL, its luminous efficiency was lower than that of line type FFL (Fig. 5). Normally, the larger the electrode area, the larger the electric current on the electrode during the plasma discharge. Because of the larger number of branches of cross type FFL, higher current was carried, leading to higher power consumption and lower efficiency. For FFL using 20%Xe-80%Ar gas system, the efficiency as well as luminance of cross type FFL is higher than line type FFL, because its plasma distribution is significantly improved by adding Ar (Fig. 6(a) and 6(b)). But in case of line type FFL, the luminance and efficiency with use of Xe-Ar gas mixture did not differ from the properties with use of pure Xe gas because of unchangeable discharge shape, as shown in Fig. 6(c), 6(d), 7, and 8.

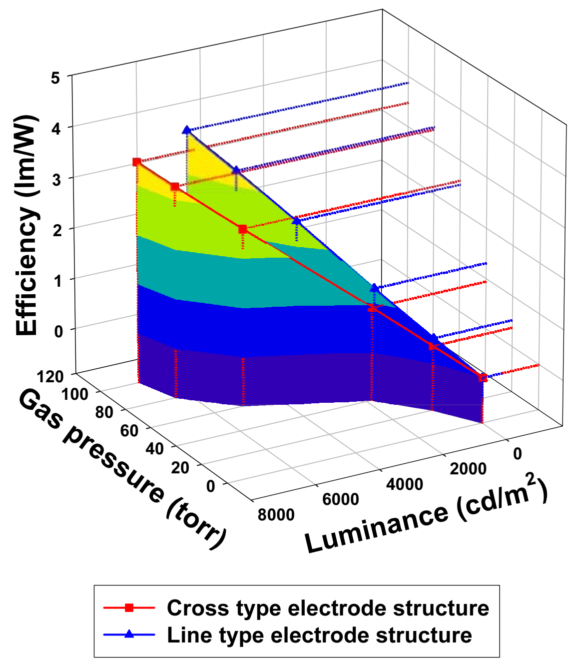


Fig. 5. The efficiency and luminance with gas pressure of FFL (sustain voltage: 1.4 kV, frequency: 25 kHz, duty: 25%, dielectric thickness: 150 µm, and distance of electrodes: 2.7 mm).

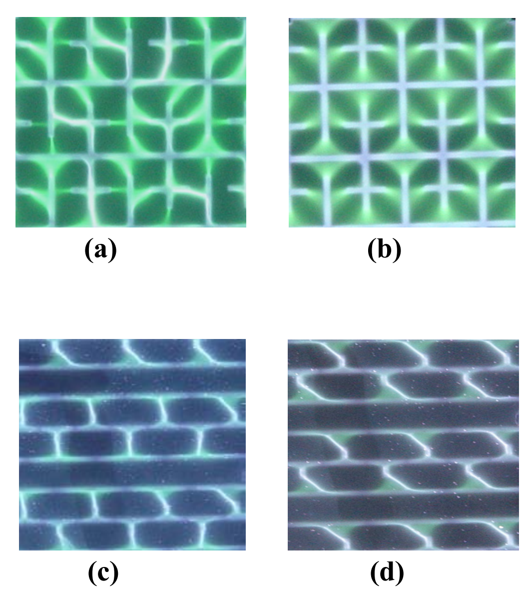


Fig. 6. Emission pictures of cross/line type FFL using (a)(c) pure Xe and (b)(d) 20%Xe-80%Ar.

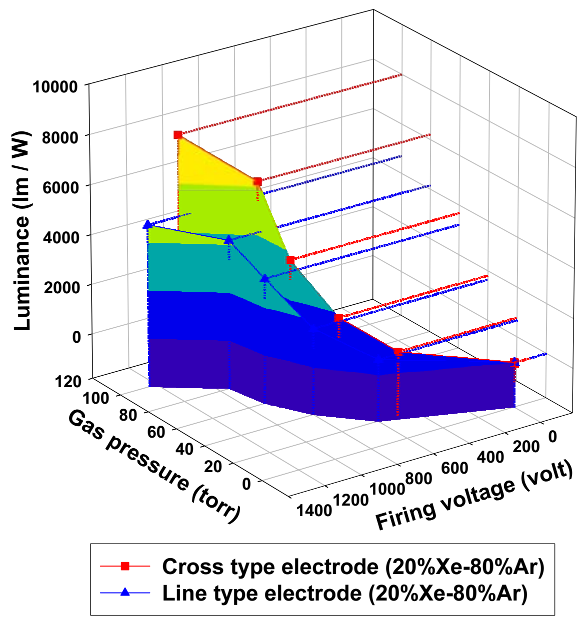


Fig. 6. The efficiency and luminance of cross type and line type FFLs with gas pressure (sustain voltage: 1.4 kV, frequency: 25kHz, duty: 25%, and dielectric thickness: 150 µm).

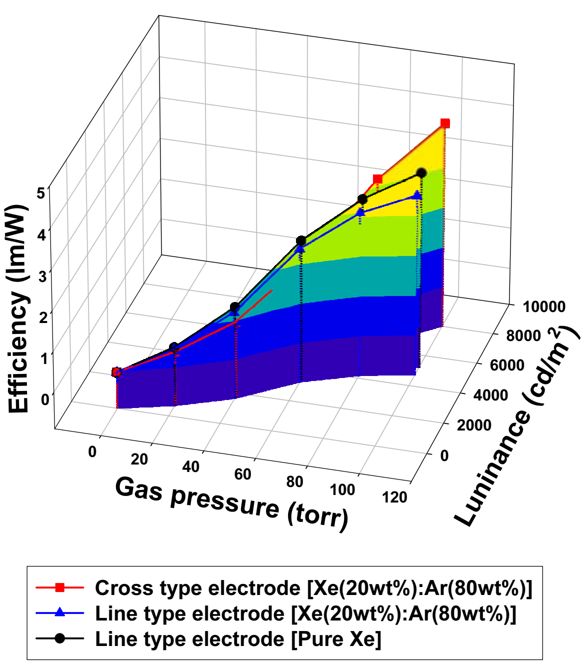


Fig. 7. Comparison of efficiency and luminance in cross and line type FFLs using pure Xe and Xe-Ar gases (sustain voltage: 1.4 kV, frequency: 25 kHz, duty: 25%, dielectric thickness: 150 µm).

4. Summary

Two types of FFL were assembled and characterized. Both types obeyed Paschen's law. Although the luminous efficiency of cross type FFL was lower than that of line type FFL using Xe gas due to its large area of electrode, the luminance of cross type FFL was higher. However the use of 20%Xe-80%Ar gas mixture caused the cross type FFL to improve luminance and efficiency due to more stable plasma condition.

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