Improvements of the luminous efficiency of mercury-free fluorescent lamps via structural and complex gas mixture changes

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Abstract

Structural parameter variation effects (changing the coplanar gap under different discharge dimensions) and use of complex gas mixtures (He, Ne, Ar and Xe) in mercury-free fluorescent lamps are studied in this paper. Pure Neon gas is the best buffer gas for obtaining high luminous efficiency in mercury-free fluorescent lamps. It is shown that with a shorter coplanar gap (30mm), a high luminous efficiency can be obtained at low operating voltage, as well as high luminance uniformity and stable discharge with a Ne-Xe 20% gas mixture.

1. Introduction

Liquid crystal displays (LCDs) are non-emissive devices that need backlighting unit. As the size of the LCDs increase in order to be used for large TV applications, the importance of backlighting increases accordingly. Recently, there have been some reports which present high luminance or high luminous efficiency mercury-free fluorescent lamps (MFFLs) for LCD applications [1]-[5]. In order to obtain high luminous efficiency, the mercury-free flat fluorescent lamp requires a gas condition of high Xe content, as well as a cell geometry having a long discharge gap. However, there are some side effects including the requirement for high operating voltages, unstable discharge that can result low brightness uniformity in the cells. In this paper, the effects of varying a structural parameter and using complex a gas mixture in MFFL have been studied. It has been found that after these parameters are optimized it is possible to obtain high luminous efficiency, as well as needing only low operating voltages for realizing the stable discharge with high luminance uniformity.

2. Experimental

The basic structure of the unit cell can be seen in Figure 1. A dielectric covered simple pair of parallel-running electrodes was used to generate the dielectric barrier discharge. The coplanar gap and the gap of the discharge space can be varied from 30mm to 70mm and from 2mm to 3mm, respectively. The electrode covered with 60μm thick dielectrics and MgO was deposited with a thickness of 4,000Å on the dielectric. White phosphor layers were formed, both on the front and rear plates, with a thickness of 6μm and 50μm, respectively. The width of the sustained square pulses was 1μs, and its frequency was 15kHz.

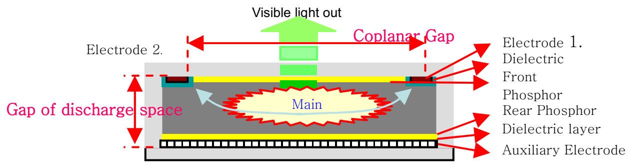


Fig. 1. Basic structure of the unit cell

3. Results and discussion

3.1 The investigation of complex gas mixture He, Ne, Ar and Xe

The discharge characteristics with complex gas mixtures (He, Ne, Ar and Xe) in MFFL has been studied. Figure 2 shows the operating voltage window as He is added to Xe 5% concentration using He and Ne buffer gas condition at a total pressure of 220Torr. The stable operation region is denoted by the shaded area where the upper voltage boundary is the contraction limit and the lower limit is the diffused voltage. The incremental rate of the diffused boundary is larger than that of the contraction limit. As the He content is increased the voltage margin becomes narrower. Finally, the stable operation region disappears when the He content reaches 50% and higher.

The operating voltage is higher, and the luminance and luminous efficiency decrease with the increase of the He content, as shown by figure 3 and the high ionization energy of the He is more dominant than the high gamma coefficient of the He in the MFFL.

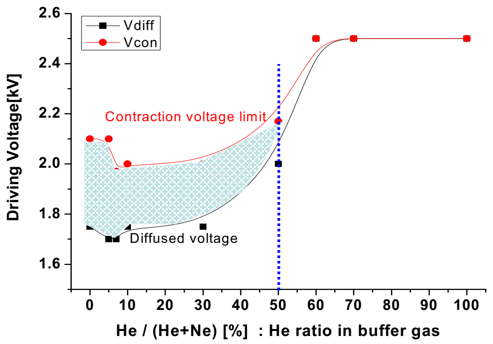
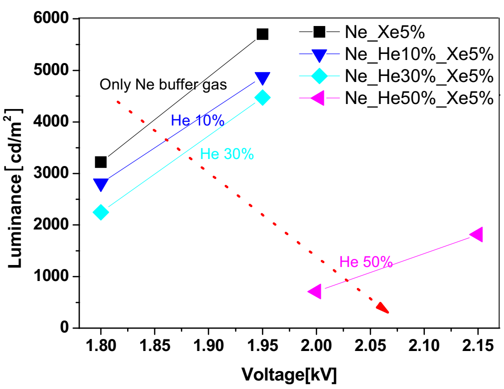


Fig. 2. The operating voltage window as a function of He content



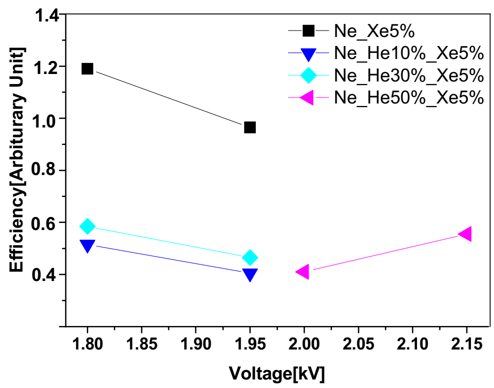


Fig. 3. The optical characteristic of He and Ne buffer gas in Xe 5% condition

Figure 4 shows the operating voltage window as a function of the Ar ratio when using an Ar and Ne buffer gas. The dotted line is the circuit limit, for a Xe content of 5%, at the total pressure of 100Torr. In contrast to He case, the voltage margin becomes wider as the Ar content increases. However, the operating voltage is also higher with increasing the Ar content in the buffer gas. Also the luminous efficiency decreases, as can be seen in figure 5 which shows the luminous efficiency at a fixed luminance of 3,000 and 4,000cd/m^2 as a function of the Ar ratio in Ar and Ne buffer gas condition with Xe 5% concentration. It could be concluded that the pure Ne buffer gas is the best proper buffer gas to obtain the high luminous efficiency in MFFLs.

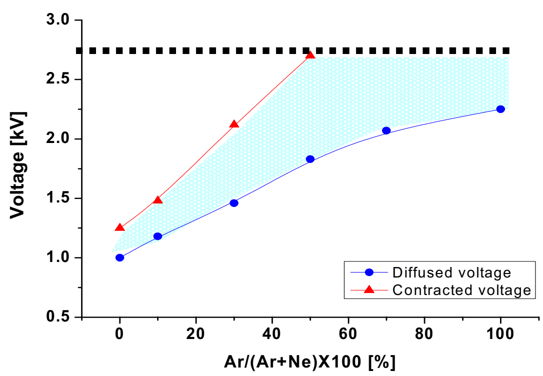


Fig. 4. The operating voltage window as a function of He content

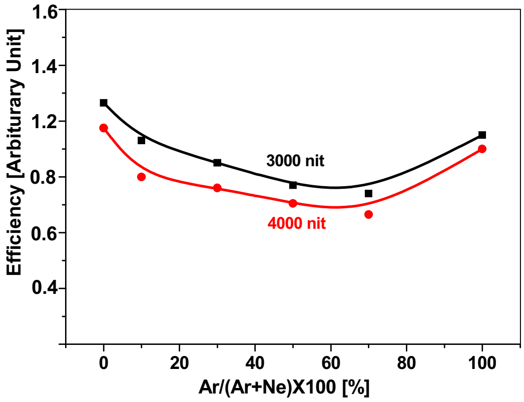
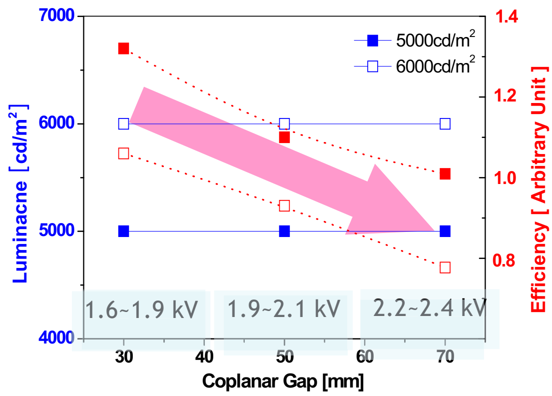


Fig. 5 Luminous efficiency at fixed luminance as a function of Ar content

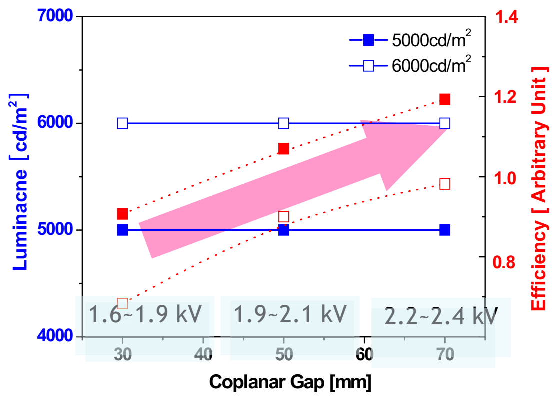
3.2 Structural parameter variations (coplanar gap variation under the different discharge dimension)

The discharge characteristic of the luminous efficiency was studied with respect to structural parameter variations. The coplanar gap and the gap of the discharge space can vary from 30mm to 70mm and from 2mm to 3mm, respectively. Figure 6 shows the luminous efficiency at a fixed luminance of 5,000 (solid symbol) and 6,000 (empty symbol) cd/m^2 with coplanar gap variations (30, 50 and 70mm) and different gaps of the discharge space (2 and 3mm). The solid line shows the luminance and the dotted line shows the luminous efficiency respectively. The discharge characteristics of the coplanar gap indicated the different behaviors that were apparent with the gap change of the discharge space. At fixed luminance of 5,000 and 6,000cd/m^2, with a 2mm gap of discharge space, the discharge efficiency decreases as the coplanar gap increases. With a 3mm gap of discharge space the discharge efficiency increases as the coplanar gap increases, as shown by figure 6. It can be seen that high luminous efficiency can be obtained by optimizing the coplanar gap and the discharge space gap. With a shorter gap (30mm), a high luminous efficiency at low operating voltage, under 2kV, can be obtained, as well as high luminance uniformity over 90% and stable discharge.

A display panel of 32 inches based on MFFL (10 by 16 cells) was fabricated and the luminance and system efficiency, including inverter loss, was measured. The attainable luminance and system efficiency are from 3,700 to 5,800cd/m^2 and from 29 to 38lm/W respectively, as shown in figure 7.



(a) 2mm gap of discharge space



(b) 3mm gap of discharge space

Fig. 6. Luminous efficiency as a function of coplanar gap at fixed luminance with different discharge space gap

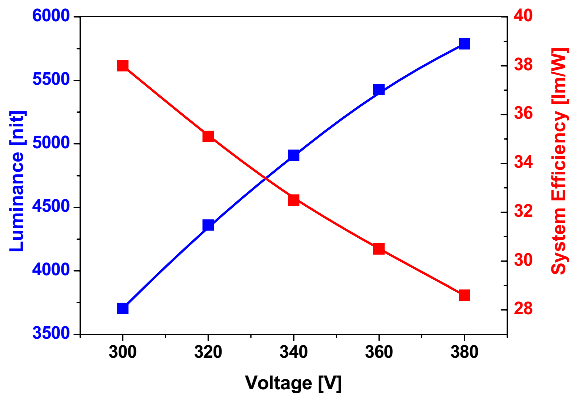


Fig. 7. Luminance and system efficiency of 32 inches MFFL

4. Conclusions

In this paper, the effects of variations of the structural parameter and gas condition have been studied to achieve high luminous efficiency in MFFLs. It has shown to result in high luminous efficiency as well as low operating voltage (under 2kV – reduction of inverter stress and EMI), stable discharge and high luminance uniformity (over 90%) in MFFL could be obtained when those parameters are optimized. Also the possibility of using thin glass (1.8mm thickness glass) has been proved which leads to a reduction of the panel weight because of the short gap (30mm electrode gap) and small cell size structure.

5. References

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