High luminous efficiency Mercury-free flat light source for LCD BLU

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Abstract

A Mercury-free, flat light source which shows high luminance and luminous efficiency simultaneously has been developed. An electrodeless, dielectric barrier discharge is used to generate the plasma using Ne-Xe mixture gas of relatively low gas pressure of a few tens torr in a 4.1 inch diagonal size of flat panel. The basic properties of the long gap glow discharge and its accompanying instabilities, which prevents us from having high luminous efficiency discharge have been analyzed. A new structure and optimized driving methods have been used to generate a glow discharge which shows a wide voltage margin of a few hundred volts. The luminous efficiency and luminance could be 110 lm/W at 1300 cd/m^2 and 50 lm/W at 5500 cd/m^2.

1. Introduction

As the size of LCD increases as they are intended to be used for TV applications, the importance of backlighting is increasing accordingly. Recently, the backlighting needs not only to be a passive lighting source but also to function actively to save energy or improve the image qualities. The LED backlighting is noticeable for its ability to provide an active driving backlighting.[1] A simple structured, flat light source without Mercury may be a good candidate considering its mass productivity and emission characteristics. There had been some research reports about the Mercury-free, flat light sources which showed high luminous efficiency or high luminance. [2]~[4] In this paper, we analyzed the discharge characteristics and optimized the performance of the newly developed Mercury-free light source which shows high luminance and luminous efficiency simultaneously. [5]

2. Experimental setup

We fabricated a 4.1 inch diagonal, flat panels which has dielectric covered electrodes separated 70mm apart as shown in Fig. 1. An auxiliary electrode was placed on the opposite substrate, and driven by proper voltage waves. The total pressure of Ne-Xe mixture was varied from 10 to 200 Torr with 4~20 % Xe concentration.

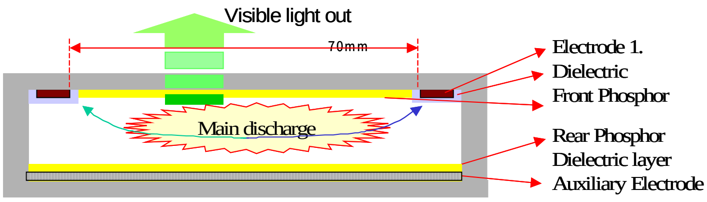


Figure 1. Structure of the flat light source

3. Result

3.1 Long gap glow discharge characteristics

A long gap glow discharge usually shows three states: The ignition, sustaining and contracted states. When sufficiently high voltages were applied to the main and auxiliary electrodes, the discharge ignited as shown in Fig. 2.1. The ignited glow discharge could be diffused to the whole discharge space and sustained under proper input power and discharge conditions as shown in Fig. 2.2~2.4. If the input power reaches to the contraction limit, the uniform glow changed to the contracted state and could not be returned its former glow discharge state before extinguished and resume from the beginning. Fig. 2.5 shows the contracted state. A plasma instability known as the thermal instability might be are responsible for this phenomenon. In most case of simple long gap dielectric barrier discharge, the ignition voltage is almost the same as the contraction limit and the ignition of discharge immediately turns into contraction state.

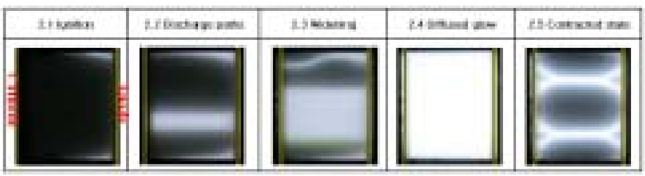
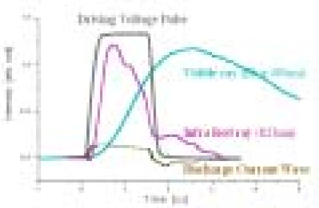


Figure 2. Visible image of the long gap discharge progress with increasing driving voltage

We carried out a detailed analysis of the sustain characteristics of the long gap discharge. We observed the time evolution of the discharge current, IR(Infrared) and visible emission to investigate the sustain discharge as shown in Fig. 3. Fig. 3.1 shows those of the stable glow discharge state. When the discharge was sustained stably, the discharge current level is low and steady which result in the high efficiency discharges. The IR ray of 823 and 828nm wave length which represents the existence of Xe excited species, emitted during the pulse period and prolonged weakly after the termination of voltage pulse because of the internal field due to the surface charges. The visible ray of blue color showed a fast response time of sub-micro second. When the contraction occurred, the discharge could not be sustained efficiently. Fig 3.2 shows the discharge current of contracted state. In this case, most of input energy was thought to be used in the ion heating process, so the discharge efficiency became very low.



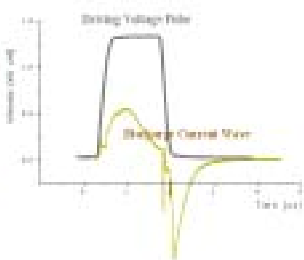


Figure 3.1 Stable glow states **Figure 3.2 Contracted states**
Figure 3. The discharge current, IR ray and visible ray during the sustain pulse period

The IR emission images during the 3µs sustain period were shown in Fig. 4, obtained at every 100ns with IICCD(Intensified Image CCD) camera. From the imaging result, the discharge progress can be explained as follow. The discharge started near the anode side at 0.5µs after the pulse applied, then it grew up fast and diffused to the center area in 0.6~0.9µs. The intensive glow was maintained during 0.9~2.6µs by the high electric field induced by the driving pulse. During this period, the negative glow appeared near the cathode area but its intensity was low. The glow discharge was going to be extinguished even though the driving voltage is still applied to the electrode as the internal field due to the surface charge accumulated on the dielectric screening out the external field. After the driving pulse off at 3µs, the weak glow still remained and re-increased slightly till about 3.5µs because of internal field. One remarkable feature is that the plasma shape is circular even though the main electrodes are two parallel, straight lines and rectangular shaped panel.

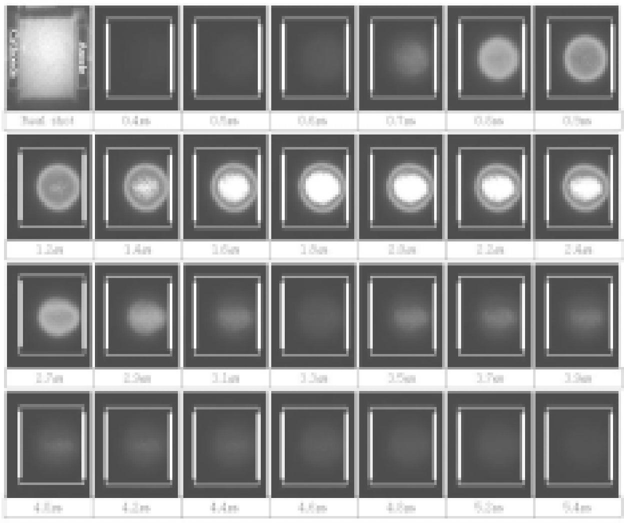


Figure 4. Spatio-temporal IR emission images of the stable glow discharge in flat panel

3.2 Driving voltage margins

In the long gap discharge with a simple pair of electrodes, it used to be very hard to secure the sufficient driving voltage margin. On the other hand, when an auxiliary electrode is deployed, a remarkable change in the operating voltage margin occurs as shown in Fig.5. The dashed line represents the ignition voltage without an auxiliary electrode. When the panel was operated with only the long gap, main electrodes, the ignition voltage was as high as that for the contraction to occur, and the discharge turned into contraction immediately upon ignition. But, when we used an auxiliary electrode, a stable glow discharge could be ignited at a lower voltage level as shown by a solid line with open circles. When we increase the input power by increasing the voltage for a given pulse period, the stable glow discharge turns into contracted one at a much higher voltage than the ignition one by as high as 400V as shown by a solid line with solid circles.

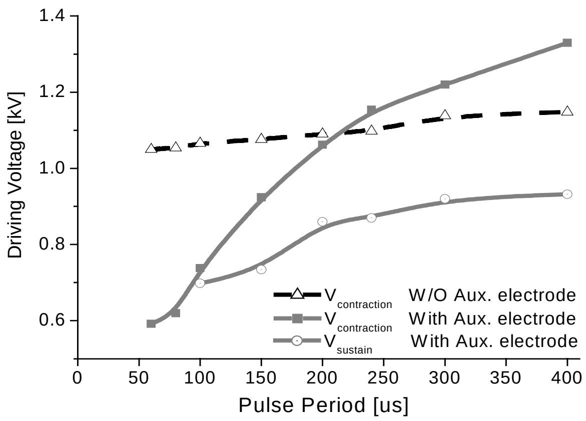


Figure 5. Operating voltage margins as a function of pulse interval

(Pulse width/interval ; 1.5/75 μs, Ne-Xe_4%, 60 Torr)

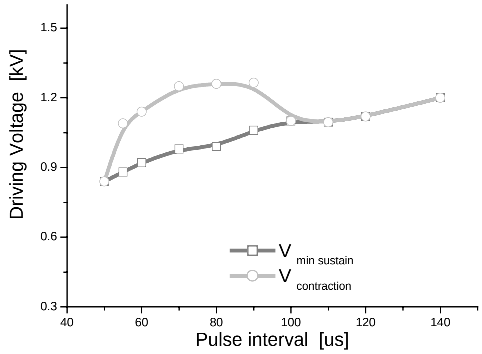


Figure 6.2 varying pulse interval
Figure 6. Driving voltage margins as varying pulse conditions (Ne-Xe_6% and 70 Torr)

The tendency of the driving voltage margin change is shown in Fig. 6 with the increasing pulse width and period. It becomes narrow and disappears as the pulse width increases as shown in Fig 6-1. Fig 6-2 shows the dependence of the voltage margin on the pulse interval. At first, the driving voltage margin increases with the period but becomes narrow after the maximum point, and then disappears. The priming particles formed in former pulse period could not be used in the following discharge if the pulse interval is too long which increases the minimum ignition voltages and reduces the driving voltage margin.

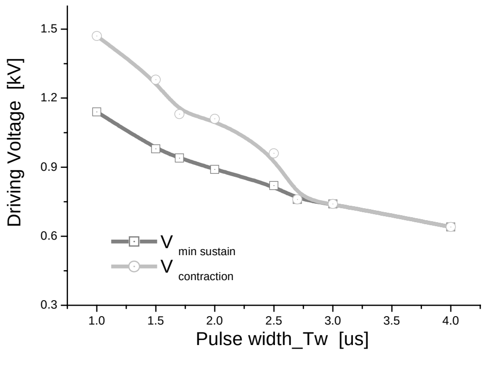


Figure 6.1 varying pulse width

3.3 Gas pressure effect

Fig. 7 shows the changes of luminance and luminous efficiency when the Xe concentration was 6%. Luminance improved with the increase of driving voltage with the decrease of luminous efficiency. For a fixed driving voltage, low gas pressure condition resulted in higher luminance but lower luminous efficiency than those of high pressure cases. Under the higher gas pressure conditions, the luminance and efficiency increased simultaneously near the lower voltage margin. At this low Xe concentration of 6%, the luminance is about 1300cd/m^2 with a high luminous efficiency of about 110lm/W.

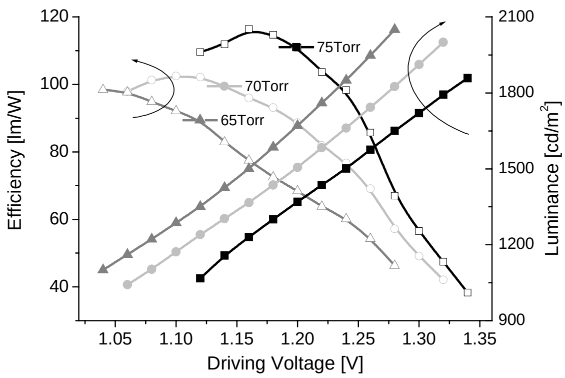


Figure 7. The luminance and efficiency as varying gas pressure

(Pulse width/interval ; 1.5/75 μs, Ne-Xe_6%)

As the Xe content is increased to 18%, the driving voltage increased and the luminance increased accordingly as shown in Fig. 8. The luminance can be 5500 cd/m^2 at the luminous efficiency of 50lm/W.

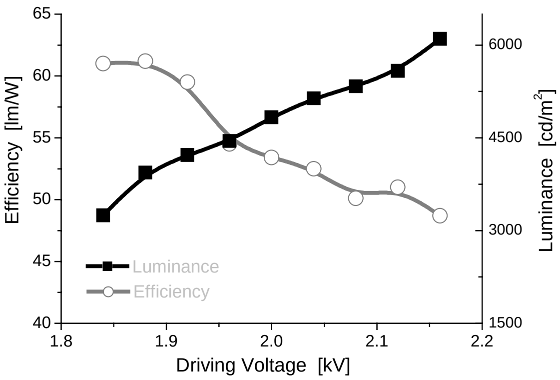


Figure 8. The luminous characteristics of high Xe contents (Pulse width/interval ; 1.5/75 μs, Ne-Xe_18%, 80 Torr)

4. Conclusions

In this work, we have studied various characteristics of a Mercury-free, flat light source with a long gap, dielectric barrier discharge type electrode structure. With the adoption of an auxiliary electrode, we could obtain significant voltage margins for stable glow discharge as high as more than 400V. By adjusting the gas and driving conditions, 5500cd/m^2 of luminance with 50lm/W of luminous efficiency could be obtained which might be sufficient for LCD backlighting application. Improvement of luminous characteristics and expand ability to larger size will be pursued in the future work.

5. Acknowledgements

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6. References

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