# A Novel Electrode Structure for Plasma Flat Backlights in LCD

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**Abstract:** *The Electrode structure has an important effect on surface discharge characteristics in plasma flat backlights, a new hexagon electrode structure was designed to increase luminance efficiency and reduce high driving voltage. 3-inch flat panels with standard parallel electrodes and new hexagon electrodes both have been made. The performance of these two panels has been investigated. The results show this new structure can not only improve the brightness and luminance efficiency but also decrease the fire voltage effectively.*

**Keywords:** surface discharge; hexagon electrode structure; brightness; luminance efficiency; fire voltage.

## Introduction

At present, LCD TV is thought to be one of the most mature technologies in flat display panels (FDP) market [1]. LCD is a non-emissive device, so the backlight unit becomes a necessary and important component. There are several backlight techniques being widely studied and used in the world now, e.g. LED, OLED, CCFL, and PFFL. The CCFL plays a leading role among all because of its excellent optical performance, but the use of mercury results in some drawbacks, such as short life time, environment pollution, a short-range operation temperatures and long build-up time to reach the saturated luminance levels etc [2]. In addition, RoSH has banned placement into the EU market of new electrical and electronic equipment containing mercury since 1, July 2006, therefore it is urgent to look for the substitute of CCFL. Plasma flat backlights with Xe-discharge possess many merits including mercury free, good uniformity and reliability [3], so it gets more and more attention by the worldwide researchers. But compared to CCFL, its lower brightness and luminance efficiency are hard to reach the market requirement, which is the urgent issue to be improved [4]. In this paper, a novel hexagon electrode structure was designed to improve the discharge characteristics.

## Theoretical Design

The basic discharging principles of plasma flat backlights are similar to the AC coplanar plasma displays (ACC-PDP). That is to fill the close discharge space with Ne/Xe mixture gas, when ac voltage is applied to the electrodes, the majority of plasma is created, Xe will be excited to high energy level and irradiate 147 and 173nm vacuum ultraviolet (VUV), which will hit the phosphor on rear glass and generate visible light.

However, the backlights should be worked as a whole, which is different from the micro cell discharge in PDP. Because the plasma flat backlight has much larger discharge space, the design of electrode structure has even larger effect on the plasma discharging. Compared to opposite discharge, surface discharge possesses many benefits including high luminance and efficiency, long life time and high uniformity, so it was adopted here to make a plasma flat backlight. Figure 2(a) shows the traditional parallel electrode structure in surface.

Elongating the distance between electrode-pairs to positive column discharge is an effective way to improve luminance efficiency [5], because positive column has the largest area for luminescence, and contributes most to luminous flux. However, long gap results in high driving voltage which is not adoptable for LCD-backlights. A special PDP software is used here to investigate the effect of distance between two parallel electrode-pairs on discharge performance [6]. Parameters are set in terms of our experiment materials. The results are shown in figure1. According to the figure, the sustain voltage increases obviously with the increase of the distance, while the discharge efficiency (the ratio of VUV emission energy to the energy of heated electronics) increases slightly with the distance increasing from 300um to 800um at the sustain voltage of 300V. And when the distance exceeds 800um, the minimums sustain voltage will exceed 300V.

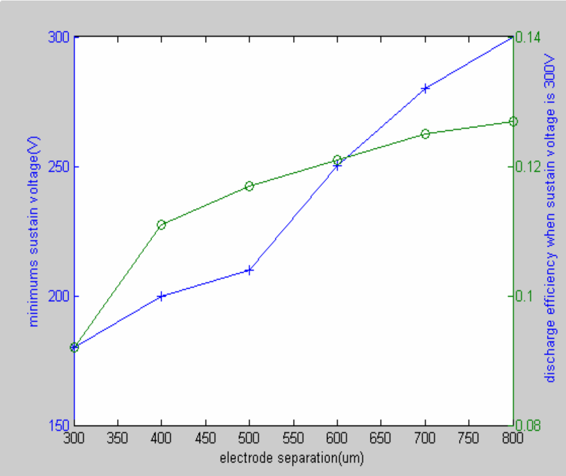


**Figure 1.** Computer simulation results of minimums sustain voltage and discharge efficiency vs. electrode separation

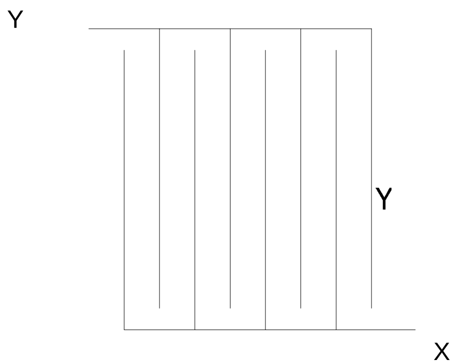


**Figure 2(a).** Traditional parallel electrode in surface discharge

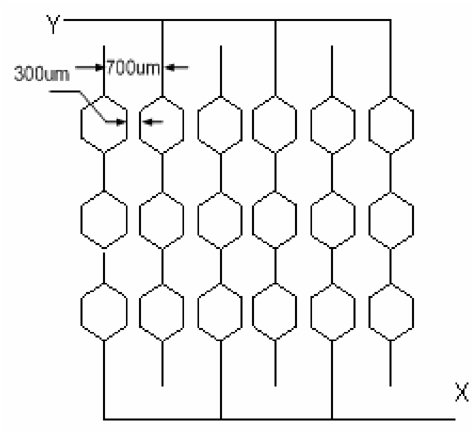


**Figure 2(b).** New hexagon electrode Structure

Considering of the computer simulation and our experiment conditions, a new hexagon electrode structure was designed as shown in figure 2(b). The distance between the parallel electrode-pair and two closest protrusive areas is 700um and 300um respectively. The protrusive area of the electrode can discharge at a relatively low voltage, then the created plasma fill the whole discharge space and decrease the panel's driving voltage.

### Experiment

*Experiment Panel Structure:* The experiment panel has only three components: a front glass plate, a rear glass plate and shadow mask strips as spacers. The front glass is 90mm*110mm, the electrode pair X and Y as shown in figure 2 run through it. A dielectric layer is covered on these electrodes. MgO film is deposited on the dielectric layer. Phosphor is sprayed on the rear glass, its area which is also the active area for the whole panel is about 50mm*55mm, 3-inch diagonal. The shadow mask strips are laid all around the phosphor as the spacer, it is 0.22mm thick. After combining the front and rear glasses, fill the discharging space with 80 torr Ne-Xe(20%) mixture gas. Finally, the experimental panel needs aging before testing.

*Driving the experimental panel:* The PDP aging circuit is used here as the experiment platform. Figure 3 shows the driving voltage waveforms added to the electrodes X,Y as indicated in figure 2. The period T of 40us is used through out the experiment. The 25% pulse duty is adopted to get the high efficiency. Figure4 shows the sketch map of the fire pulse. There is one fire pulse every 300 periods. The fire voltage is tested when the sustain voltage is fixed at 180V. Figure 5 shows the photo of 3-inch experimental panel with Hexagon electrode structure (a is the picture of whole lightening panel and b is the hexagon electrode structure).

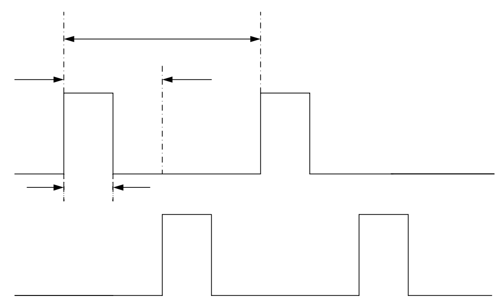

**Figure 3.** Driving voltage waveforms

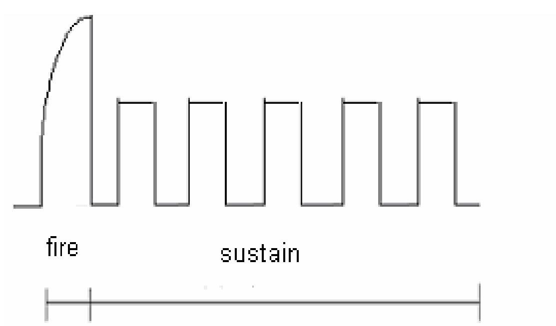


**Figure 4.** The sketch map of fire pulse

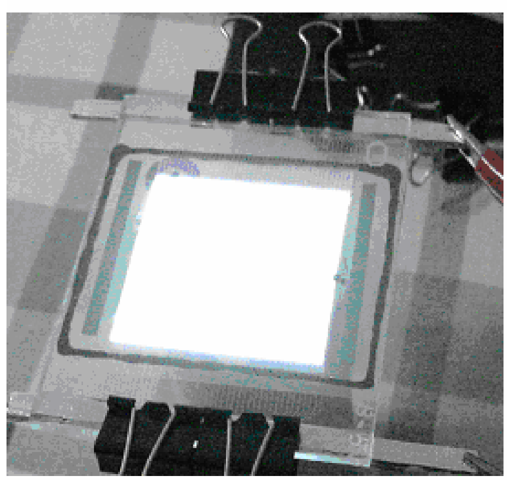

**Figure 5(a).** 3-inch experiment flat panel

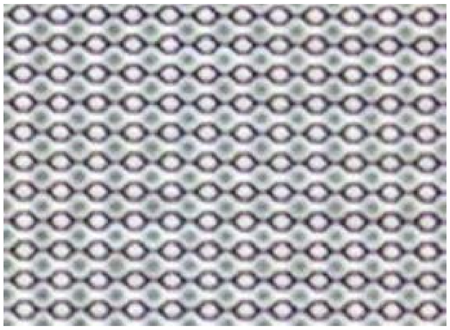

**Figure 5(b).** Hexagon electrode structure

### Results and Experimental Analysis

Table 1 shows that the hexagon electrode structure can decrease the fire voltage effectively. Because at the same voltage, the electric field in hexagon structure is much stronger than the parallel one, and the gas pressure in both panels is the same, so the E/P value in hexagon panel is larger which means at the same voltage, electronics can obtain more energy during collision, therefore, the fire voltage decreases.

Figure 6 shows the brightness as the function of sustain voltage. According to the figure, the two panels' brightness both increases with the increase of sustain voltage gradually. At the same voltage, the brightness of hexagon structure is larger than the parallel one. Because the higher E/P value in hexagon structure leads electronics obtain more energy, then more electronics excite Xe, generate more 147 and 173nm vacuum ultraviolet (VUV) to hit the phosphor, the brightness increases. The experiment results illuminate 240V is the optimum operating voltage for the new hexagon electrode structure, because at this point it shows better discharge capability than the vicinity voltages, its brightness 212 $cd/m^2$ even exceeds the parallel one's 192 $cd/m^2$ at 300V.

The brightness values are tested by PR-715 spectrascan radiometer.

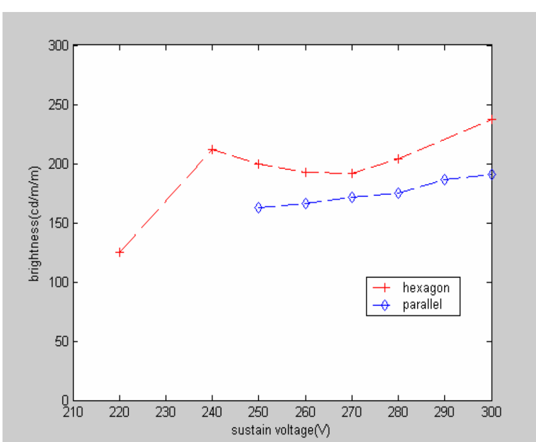


**Figure 6.** Brightness vs. sustain voltage for different electrode structures

**Table 1.** The fire voltage and minimums sustain voltage for the experimental panel

| Electrode structure | Fire voltage | Minimums sustain voltage |
|---|---|---|
| Hexagon | 220V | 193V |
| Parallel | 360V | 250V |

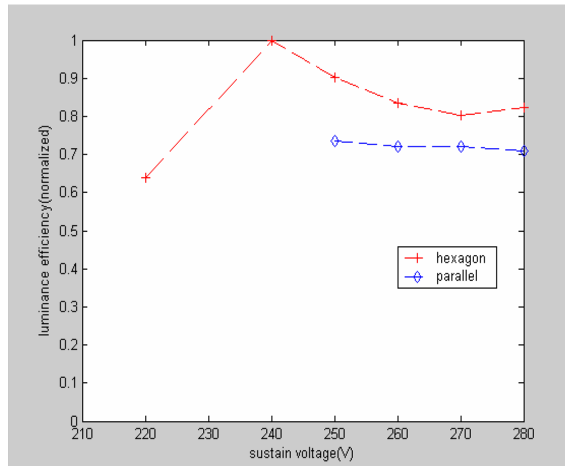


**Figure 7**. Luminance efficiency vs. sustain voltage for different electrode structures

The effect of luminance efficiency on sustain voltage has been shown in figure 7. Theoretically, luminance efficiency decreases with the increase of sustain voltage gradually, because with the increase of voltage, electronics obtain more energy, large numbers of electronics ionize rather than excite Xe which results in lower efficiency. But in this experiment, we found that there is a max luminance efficiency value with the increase of operating voltage for the hexagon electrode panel which is different from the parallel electrode panel whose results accord with the theory perfectly. It is the effect of protrusive-area. The special protrusive-area in the hexagon structure can form multi-different discharge paths rather than the single one in standard parallel structure. The discharge intensity is the accumulation of discharge particles generated by different discharge paths. The accumulation effect varies with the operating voltage, the results reveal it performs best at 240V. In addition, according to the figure7, at the same voltage, the hexagon structure's efficiency is higher than the parallel one. Because the resistance of plasma is very small, the operating current does not depend on the distance between the electrode pair [7], therefore, at the same voltage, the power consumption of these two panels is almost the same, then higher brightness will result in higher luminance efficiency.

### Conclusion

A novel electrode structure has been designed in this paper to improve the surface discharge characteristics. The experiment results show that the newly designed hexagon electrode panel has 140V lower firing voltage, 23% larger brightness and 36% larger luminance efficiency than the standard parallel electrode structure under the same operating voltage. At the voltage of 240V, it has the best discharge performance. This new structure could be considered as a useful technology for plasma flat backlights.

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