A new Areal Selective Dimming Method of Mercury-free Flat Fluorescent Lamps for LCD Backlighting

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Keywords: Areal selective dimming, flat light source, Xe discharge

Abstract

A new mercury-free flat fluorescent lamp with a single cell having dimension 2.2inches across the diagonal, had been developed which shows a wide, stable operating voltage margin, high luminance and luminous efficacy by adopting the bipolar pulse drive scheme. In this paper, the single cell is expanded into a multi-structured configuration to realize a 32inch sized panel across the diagonal by a simple repetition of the single cells. A driving scheme is proposed for a 2-bit areal selective dimming using dual auxiliary electrodes and bipolar drive scheme.

1. Introduction

Since liquid crystal displays (LCDs) have been successfully developed and mass produced for laptop PCs in the early 1990's, they have become one of the main display devices in a wide application areas such as mobile displays, computer monitors and digital TV screens. However, as LCD extend their application areas to the newer large size TVs, the conventional backlighting system using cold cathode fluorescent lamps (CCFLs) is facing several technical problems. As the length of the fluorescent lamp increases to accommodate the larger size needs, the number of lamps for one LCD unit increases accordingly. Also the use of Mercury in CCFL is causing environmental concerns; as well its severe temperature dependency [1-3].

This paper proposes a new Mercury-free flat fluorescent lamp (MFFL) for LCD backlighting unit which shows a wide, stable operating voltage margin, high luminance and efficiency [4-5]. In this paper, the operating voltage characteristics of a single cell with 2.2 inch diagonal size has been studied and expanded to a multi-cell 32-inch lamp [6], in which the bipolar pulse drive waveform and dual auxiliary electrodes are used to achieve more stable discharge operation and wide voltage margin. A new driving scheme is proposed for the 2-bit areal selective dimming control.

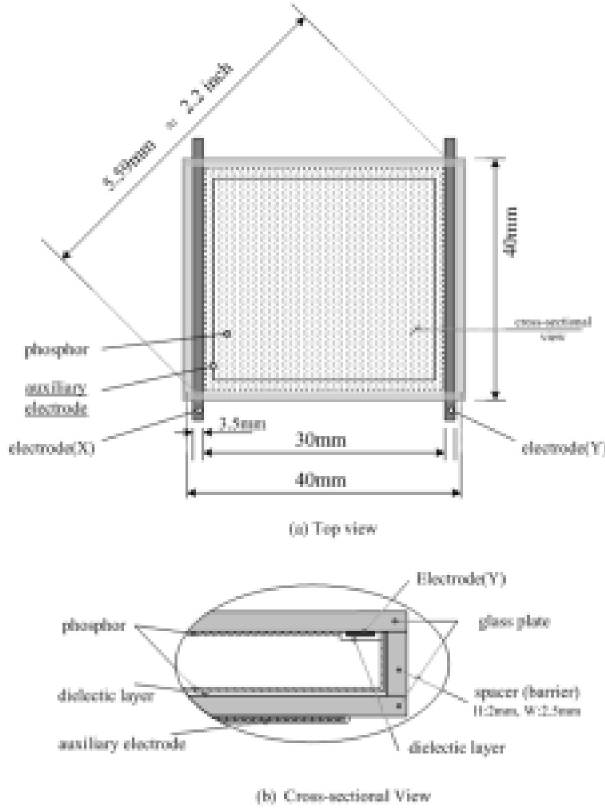


Fig. 1 Top-view and cross sectional view of the single MFFL

2. Experimental work

The top- and cross-sectional views of a unit cell are shown in Fig. 1. The two parallel-running main electrodes are separated by 30mm and are covered by a dielectric material. The phosphor is printed on the inner surface of both plates, as shown in Fig. 1-(b).

The auxiliary electrode is located on the opposite plate and used as the data electrode for selecting the cells. A Ne-Xe (18 %) gas mixture was used as the discharge gas.

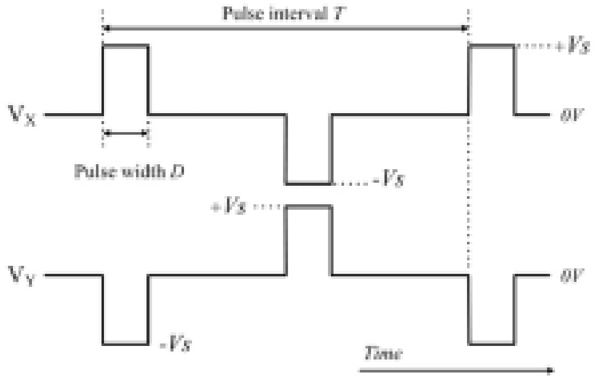


Fig. 2 Bipolar pulse drive waveforms

Dual auxiliary electrodes with grid shaped line electrodes are formed on the opposite plate of the main electrodes instead of the conventional auxiliary electrode with the quadrangle-shaped line.

As shown in Fig. 2, the bipolar pulses, with a height of 1–2 kV and frequency of 10–24 kHz, were employed to give short pulsed excitation in the discharge space that is filled with the Ne-Xe gas mixture. In the conventional drive scheme, the unipolar pulse drive, having a much higher voltage is needed to generate a fully diffused glow discharge that raises the probability of the transition to the contracted discharge because the breakdown voltage between the main electrodes is much higher than that between one of the main electrodes and the auxiliary electrode. However, symmetric and similar voltage distributions can be obtained by using the bipolar pulse drive scheme and dual auxiliary electrodes. The pulse width *D* is fixed at the 1.5μs in the experiment.

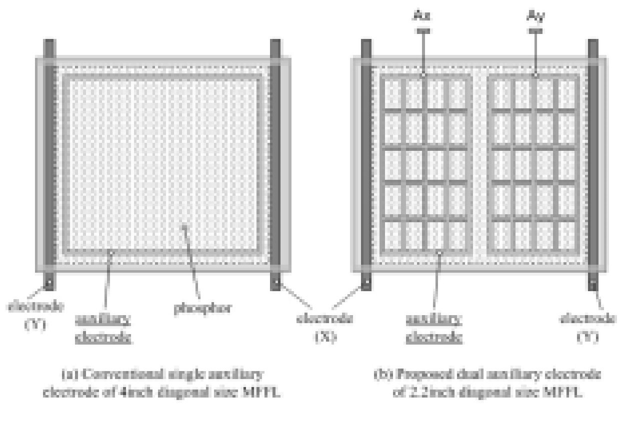


Fig. 3 Conventional and proposed dual auxiliary electrode

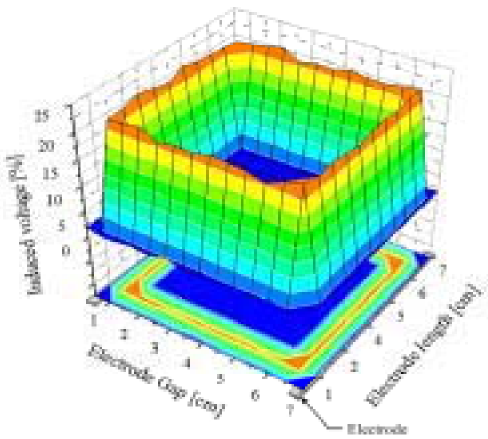
3. Results and discussion

In general, an increase of the distance between two electrodes causes the discharge voltage to increase. As shown in Fig. 1-(a), the low voltage operation was obtained by the help of the auxiliary electrode, placed near to the main electrode on the opposite glass plate. However, the discharge condition is varied by the voltage conditions applied to the auxiliary electrode. Auxiliary electrodes have two important constitutions. One is a parallel component which generates a local discharge at low voltage levels, and the other is a perpendicular electrode component which makes discharge channels between the main electrodes. So we could confirm the similar and stable discharge generation of fully diffused glow discharges at various auxiliary electrode structures, with one or more vertical and parallel electrode components. it is helpful to achieve the fully diffused glow discharge in the low voltages and the whole discharge space.

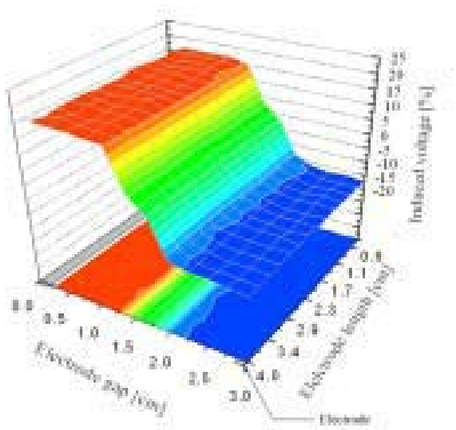
Contrary to the previous work [7], a high Xe partial pressure of more than 18Torr was applied over 18torr, and the main electrode gap of 30mm was optimized with the improvement of the luminance and the luminous efficacy. With the high Xe partial pressure, the operating voltage margin is decreased and the instability of the diffused glow is increased. To reduce these drawbacks of the application of high Xe, the dual auxiliary electrode and bipolar driving scheme was devised. The bipolar driving scheme, as shown in Fig. 2, can reduce the level of the operating voltages and decrease the instability of the diffused glow discharges, due to the lower difference of the voltage between the main and auxiliary electrodes. Also the dual auxiliary electrode, as shown in Fig. 3, can be used to control the state of the induced voltage on the auxiliary electrode.

Fig. 4 shows the distribution of the induced voltage on the auxiliary electrode. In the case of the conventional 4inch diagonal size of MFFL, using the single auxiliary electrode with a quadrangle-shaped line, the induced voltage on the auxiliary electrode is shown in Fig 4-(a). The induced voltage is approximately 24% in this experiment, when the voltages of 1 kV is applied to the electrode X and a local discharge takes place followed by a flat discharge as applied voltage is increased.

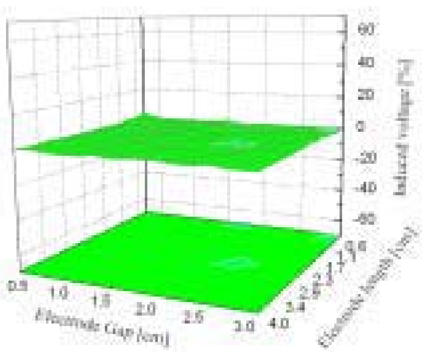
As shown in Fig. 4-(b), with the dual auxiliary electrodes disconnected, the induced voltage on the auxiliary electrode varies from position 0cm (electrode X) to 3cm (electrode Y) when the voltage of 1kV is applied to electrode X and that of -1kV applied to electrode Y. The voltage difference between the main and auxiliary electrodes is smaller than the ignition voltage, thus, the cell remains in the OFF state.



(a) Induced voltage distribution at the conventional single auxiliary electrode and unipolar pulse driving scheme



(b) Induced voltage distribution when the dual auxiliary electrode is disconnected with the bipolar pulse driving scheme



(c) Induced voltage distribution when the dual auxiliary electrode is connected with the bipolar pulse driving scheme

Fig.4. Induced voltage distribution on the state of the auxiliary electrode connection

Meanwhile, when the dual auxiliary electrodes are connected, the induced voltage has the middle electric potential of the applied voltage symmetrically across the main electrodes, as shown in Fig. 4-(c). The induced voltage on the auxiliary electrode is maintained at around 0V and the voltage distribution causes a greater voltage difference between the main and auxiliary electrodes than the ignition voltage, so that ignition discharge occurs and moves to the fully diffused glow discharge state. This characteristic can be used to decide the areal selective ON/OFF state of the chosen cell in the large sized, multi-cell MFFL.

Fig. 5 shows the drive voltage waveform for the areal selective dimming in multi-structured MFFL case which uses a 32inch diagonal sized panel with the matrix structure of the 16 x 10 cells. A television frame is divided to two subfields where a subfield consists of the addressing period and the sustaining period. During the addressing period, the addressing data is written to each cell line by line. Auxiliary pulses are applied to each auxiliary electrode which is generating the voltage waveform scaled by the turn ratio of the transformer. When the dual auxiliary electrodes of the cell to be turned ON are connected and grounded, the cell emits light during the sustaining period. When the dual auxiliary electrodes are disconnected and the auxiliary voltage pulses are applied to each auxiliary electrode with the same polarity of the adjacent main electrode, a flat discharge is not generated.

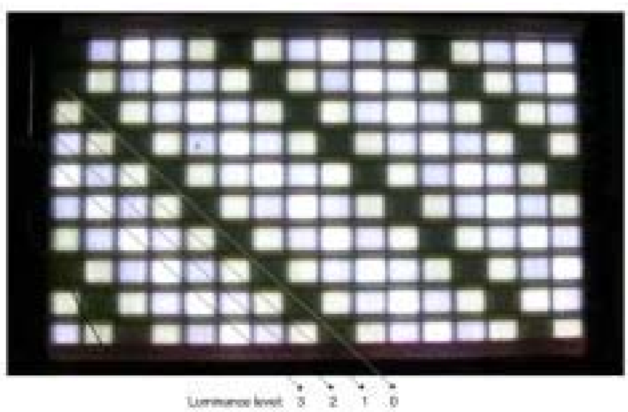


Fig. 6 Areal selective 2bit dimming in the 32inch multi-structured MFFL

Fig. 6 shows a still image of the 2-bit dimming in the 32inch multi-structured MFFL where it is possible to see 4 different luminance levels from the OFF state through to level 3, according to the subfield driving method with the 2^0, 2^1 luminance weightings.

4. Summary

A new driving method is proposed for the areal selective 2-bit dimming of a multi-cell structured MFFL with the bipolar pulse drive scheme and the dual auxiliary electrodes that can attain a wide voltage margin and high luminance with high Xe partial pressure and will allow a significant improvement of the gray scale expression capability and the power reduction of LCDs.

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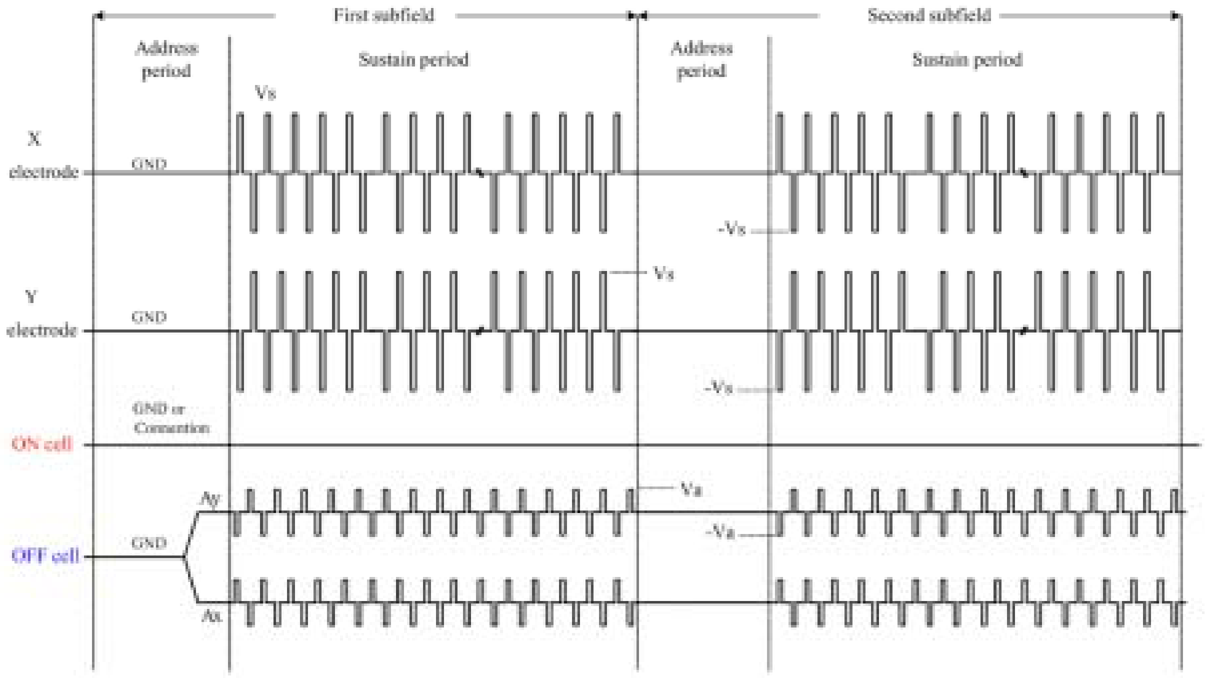

Fig. 5 Drive voltage waveform for areal selective 2bit dimming control