Abstract

An experimental, 32-in.-diagonal Hg flat discharge fluorescent lamp was developed for an LC-TV backlight. An electron density in the lamp is 1/20 and VUV phosphor load is 1/160 of the conventional EEFLs. With a proper lamp design, current density at the electrodes may be reduced to 1/3 of the EEFLs. These ensure longer lifetime and higher efficacy. The ignition voltage is relatively low at 700V.

1. Introduction

Along with an increase in the diagonal size of LC-TVs, larger area backlights are required. To cope with the requirement, CCFLs as long as 1600mm have been introduced. The long lamps however suffer from high ignition voltages, especially under low environmental temperatures. Also the number of CCFLs or EEFLs placed behind the LC panels has to be increased together with an increased number of inverters and complexity of the backlight unit structure.

In order to simplify the structure and also to ensure long lifetime under severe conditions required for TV expression, a use of Hg flat discharge fluorescent lamps is suggested. Such lamps of small sizes have already been reported elsewhere[1]. An objective of this study is to enlarge the lamp area to 32 inches diagonal. A key to realize this is to eliminate contraction of the discharge and to provide a uniform emission from the entire area. This is made possible by dividing the lamp into multiple channels having an optimum width, and also by choosing adequate drive voltage waveforms.

2. Lamp Structure

Figure 1 shows a structure of the newly fabricated experimental lamp. The active area is 700mm x 420mm, 32-inch diagonal. The lamp has only two components; a front glass plate and a rear glass vessel with embossed ribs. The width and height of the ribs are 1mm and 2.8mm, respectively, and they separate the lamp into 14 discharge channels, 700mm x 30mm each. The lamp contains 13kPa Ne+Ar(3%) and Hg. Phosphor is deposited on the inner surfaces of the both substrates. The phosphor layer on the front glass plate is thinner that that on the real glass vessel. The output light may be extracted from the rear side if the phosphor thicknesses are properly adjusted.

The electrodes run along the ribs, with the electrode separation being almost equal to the channel width. Discharges occur laterally across the channels, not longitudinally along the channels[2]. For the present experiments, the electrodes are placed outside of the front glass plate, allowing various kinds of measurements including discharge stability and effects of electrode separation. Because of high impedance due to the
thickness of the front glass plate, however, absolute values of luminance and efficacy cannot be measured. In a final version, the electrodes will be placed inside of the glass plate and covered with ~50µm-thick dielectric layers as shown in Fig. 2 (a) or (b). The lamps with the identical structure, but smaller in the diagonal size (5.2-in. diagonal), achieved 30,000cd/m² and 50 lm/W[3].

3. Driving of Lamp

Figure 3 (a) shows electrode connections for the configuration of Fig. 2 (a), and Fig. 3 (b) shows drive voltage waveforms. Throughout the following experiments, pulse interval \( T \) of 40µs and pulse width \( \tau \) of 20µs were used. This is because 50% pulse duty \( (\tau/T = 0.5) \) has been found to give the highest efficacy from the previous experiments[3]. Since the discharges are driven across the dielectric layers, the capacitance of the layers act as ballast impedance and the 14 channels of the lamp need only one common inverter. Alternatively, each channel can be driven individually with its own inverter to perform the blinking backlight operation for improving the moving image quality[4], or to adopt an adaptive dimming technique for reducing the lamp power consumption[5].

Since the electrodes are insulated with the dielectric layers, the discharge current terminates by itself within a short period. This helps to suppress the discharge contraction. Then a uniformly diffused discharge fills the channel, and the luminance uniformity across the channel and along the channel are good. Driving condition such as voltage, pulse width, and pulse interval are also important factors for suppressing the discharge contraction.

The channels become longer as the lamp area becomes larger. If a sinusoidal voltage, instead of the square voltage of Fig. 3 (b), is applied to such long channels, many column-shaped discharges of Fig. 4 are formed between the electrodes. For obtaining a uniform diffusive discharge, it is essential to establish a discharge as quick as possible by using fast rise square pulses.

4. Electrode Separation

By using the lamp of Fig. 1, various experiments were performed to study the behavior of the lateral multi-channel lamp. In the experiments of Figs. 5, 6, 7, and 8, the electrodes are placed perpendicular to the ribs (unlike Fig. 2) and the electrode separation was varied from 10mm to 200mm. The width of the discharge columns therefore was 30mm. Figure 5 shows variation of luminance as a function of voltage for various electrode separations. The luminance increases linearly with the voltage increase. Figure 6 indicates that, when the voltage is kept constant, luminance increases with an increase of the electrode separation, but saturates when the separation exceeds 40mm.

Figure 7 shows variation of luminous efficacy as a function of electrode separation. As the separation becomes larger, the efficacy increases because of establishment of a longer positive column which has an intrinsically high efficacy nature. The maximum values of the electrode separation in Figs. 6 and 7 are determined by the formation of contracted discharges. The electrode separation (corresponding to the channel width of Fig. 1) of 20mm - 120mm, therefore, are preferable for large area backlights.

![Figure 5. Luminance vs. voltage for various electrode separations.](image)

![Figure 6. Luminance vs. electrode separation for Hg flat discharge lamp. Voltage: 800V.](image)
An ignition voltage $V_i$ and an extinction voltage $V_e$ increase as the electrode separation becomes larger, Fig. 8. In the figure, $V_c$ is the critical voltage below which the discharge is not diffusive. It should be noted that the extinction voltage is about a half of the ignition voltage because of accumulation of wall charges on the insulating dielectric layer. These charges create an internal electric field which assists the discharge breakdown when the succeeding drive voltage pulse is applied. If the electrodes are placed inside of the front glass plate as shown in Fig. 2, the ignition and extinction voltages become lower.

5. Electrode Length

For obtaining larger lamp areas, the number of channels (14 channels for the case of Fig. 1) having an optimum channel width (30mm for Fig. 1) should be increased. Also the channel length (i.e., the electrode length, 700mm for Fig. 1) should be made longer. Figures 9 and 10 show variations of luminance and luminous efficacy as a function of electrode length when the drive voltage was 800V. It can be found from these figures that the luminance and luminous efficacy do not depend on the length of electrodes, showing that there is virtually no limitation on the channel length in terms of electro-optical performances.

6. Lifetime Considerations

Of special importance to the backlight units for LC-TVs is their lifetime. Luminance requirement assessed to the backlights are becoming severer in order to increase the peak luminance of TV sets still further, and also to improve picture quality of moving images when such a technique as blinking backlight[4] is utilized, and also to increase the peak luminance still further. For instance if we want to achieve a peak LC-TV luminance of 800cd/m², then the peak output luminance from the backlight unit should be as high as 20,000cd/m². This requires CCFLs or EEFLs to be driven at very high discharge current levels. For CCFLs, once the cathode drop voltage is of such a value to commence sputtering, the sputtering rate of the internal electrodes increases proportional to the current density to the 2.5th power, thus the lamp lifetime is shortened drastically.

Although there is less sputtering in EEFLs, one has to consider an electrode damage under high electrode current[6]. Also dielectrics in the vicinity of the electrodes are damaged due to exceedingly elevated temperature. The presence of an intense electric field makes the condition even worse. In the worst case, a punch-through of the glass tube wall destroys the lamp. As the required luminance becomes higher, VUV also becomes more intense, shortening the phosphor, diffuser, polarizer, and filter lifetimes.
Current density at the electrodes, electron density in the discharge volume, and VUV load of the phosphor particles can be reduced, while maintaining the output luminous flux, through an adoption of the flat discharge fluorescent lamp structure introduced here. If a 32-in.-diagonal flat lamp consisting of 4 channels with 20mm-wide electrodes is employed instead of 16 EEFLs having a 2.6mm diameter and 30mm-long electrodes, for instance, the total electrode area is increased by a factor 100 and the current density at the electrode is reduced by a factor 3, implying that the electrode power density, and hence the temperature of the dielectrics can be lowered.

An electron density is reduced to 1/20, assuring higher efficacy due to reduced degree of VUV imprisonment. The discharge contraction becomes less likely to take place with lower current density in the discharge volume, and therefore the reduction of the electron density is desirable. Also the total phosphor area is increased by a factor 8, reducing the VUV load to the phosphor particles by a factor 160.

Although the luminance lifetime (the interval during which the lamp luminance is reduced to 50% of its initial value) of each CCFL or EEFL may be as long as 60,000 hours, not all the lamps in a backlight unit do not deteriorate at the same rate. This results in non-uniformity across the backlight unit area, limiting a further use of the backlight unit. The flat discharge lamp has only one vacuum vessel, and thus the luminance deterioration is expected to be more uniform across the entire area compared to the case where many independent EEFL lamps are utilized.

### 7. Conclusions

An experimental, 14-channel, 32-in.-diagonal mercury flat discharge fluorescent lamp has been developed for an LC-TV backlight. The lamp structure is simple with only two components; a front glass plate and a rear glass vessel having embossed ribs. The discharge current flows not longitudinally along the channel, but laterally across the channel. The key to enlarge the flat discharge lamp area is to eliminate contraction of the discharge and to provide uniform emission. This is made possible by dividing the lamp into a multiple number of discharge channels.

As the channel width becomes larger, the ignition and operating voltages increase and also a flat uniform discharge becomes unstable. For the present lamp, the channel width between 20mm and 120mm was found preferable. Because of the shorter channel width (i.e., shorter electrode separation) compared with that of the conventional CCFLs or EEFLs, the ignition and operating voltages are lower. The lamp needs only one inverter for all the channels. The electrode length was found to have no influence to luminance and efficacy, suggesting that the lamp diagonal may be extended to sizes larger than 32 inches.

By properly designing the structure of the flat discharge fluorescent lamp, the current density at the electrodes can be reduced by a factor 3, current density in the discharge volume by a factor 20, and VUV load of the phosphor layers by a factor 160 compared to the conventional EEFLs. These imply that damages to the electrodes, dielectric layers, glass tubes, and phosphor can be reduced. An electron density of the lamp is 1/20 that of EEFLs, assuring higher luminous efficiency and less chances of discharge contraction. The lifetime of the backlight unit with multiple CCFL or EEFL lamps may be determined by luminance non-uniformity between these lamps, since all the lamps do not deteriorate at the same rate. In this respect, too, the lifetime expectancy of the backlight unit with the present flat discharge lamp is longer.

### 8. References


