Electrooptic characteristics of flat fluorescent lamps depending on the driving conditions

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Abstract

The electrooptic characteristics of 32-inch multi-channel-structured, mercury-type flat fluorescent lamps have been investigated in detail. The luminance and the lamp current/voltage have been monitored by changing the driving conditions such as duty ratio, backlight conditions. It was found that the efficiency became the maximum at the duty ratio of 50 % with a nearby metal plate.

1. Introduction

The backlight unit (BLU) technology has become the core component of the large-size liquid crystal display (LCD). Various light sources have been developed and adopted in the BLU such as light-emitting diodes, flat fluorescent lamps (FFLs), field-emission lamps, etc. [1]. Among them, FFL backlight technology has attracted great attention owing to the possibility of simple backlight structure, better luminance uniformity and cost down and has recently been commercialized [2]. Mercury(Hg)-type FFLs can be categorized into true-FFLs having a rectangular parallelepiped discharge space, serpentine-type FFLs and multi-channel-structured FFLs. Among these technologies, multi-channel-structured FFLs have become the mainstream technology for the application of large-size LCD backlights.

The cross-section of multi-channels is usually non-circular, different from the conventional tubular fluorescent lamps [3]. This unusual condition of the discharge space needs more sophisticated approach to the lamp design for achieving better lighting performances. However, detailed electrooptic characteristics of multi-channel-structured FFLs have not yet been reported. The present contribution is aimed at reporting electrooptic characteristics of multi-channel-structured, mercury-type FFLs driven by square waves. Changes in electrooptic properties depending on driving conditions including duty ratio and the existence of nearby conducting plates will be reported, which can be used as basic data for the optimization of the performances of mercury-type FFL backlights.

2. Experimental

FFLs for 32” BLU have been fabricated by the glass-forming technology [4]. One FFL consists of 28 channels whose cross-sections are semi-elliptical with a height of 3.7 mm and a width of 10 mm. It was found that the electrooptic properties of FFLs were not sensitive to the exact number of channels in the range of 24~32 channels if the discharge length was the same. Inert mixture gases consisting of neon and argon in addition to small amount of liquid mercury have been used for the formation of glow discharge and UV(ultraviolet) light generation in FFLs. Phosphor layers were sprayed onto two inner surfaces of the upper and lower glass plates and an additional reflection layer was inserted between the lower glass plate and the lower phosphor layer for reflecting the generated light toward the LCD panel. The lower glass plate of FFL was flat while the upper glass plate was multi-channel-structured. Dual-coplanar-type external electrodes were formed by using cupper tapes at both ends of FFL for applying high voltages. The electrode width was 15 mm. Manufactured FFLs have been aged for about 2 hours for obtaining uniform brightness over the whole area via mercury diffusion and initial stabilization of phosphor layers.

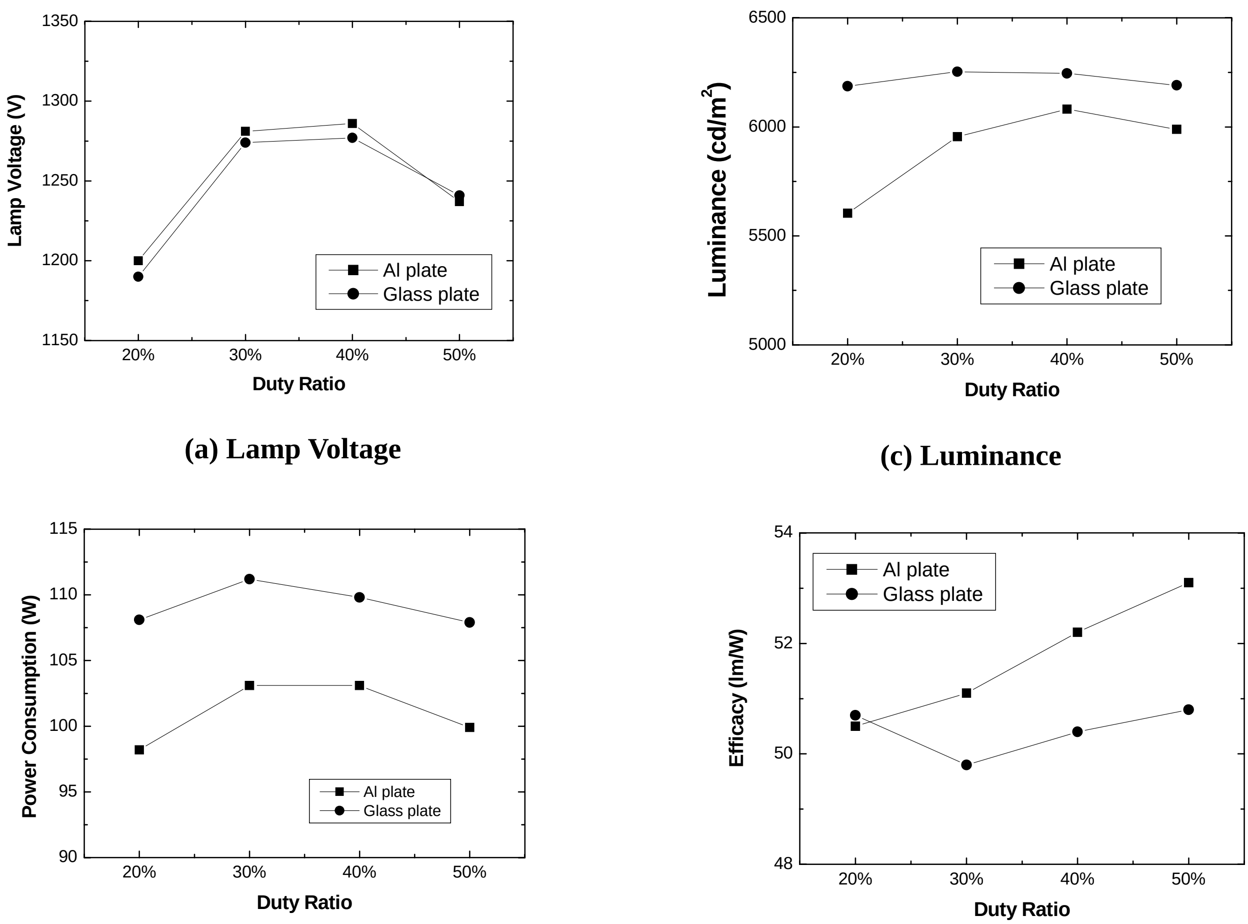
An aluminum(Al) plate was fabricated for simulating the condition of the back chassis of the conventional backlight. A FFL was put over the metal chassis, which was covered by a diffuser plate for homogenization of the emitted light from multi-channels. For comparison, the Al chassis was replaced by a glass plate in order to reveal the effect of the metal plate on the electrooptic properties of FFLs. All optical properties were investigated on the diffuser plate. Three FFLs have been evaluated and the averages values will be reported in the next section.

FFLs were driven by a high-voltage driving equipment (HPI500P, FTLAB). The driving frequency and the duty ratio were changed at a fixed lamp current, and the change in efficiency was monitored by evaluating the luminance and the power consumption. During measurements, the discharge current was fixed to a certain value using the current probe(Tektronics P6022), and the lamp voltage was monitored by the high voltage differential probe(Tektronics P5210). The ambient temperature during the measurement was kept to 25±1^{o}C. However, the cold-spot temperature was not strictly controlled to a constant value, and this condition is expected to induce some variation in the measured values during the measurements.

3. Results and discussion

Figure 1 summarizes the change of the lamp voltage(V_L), the power consumption(P_L), the luminance(L) and the efficacy(η) as a function of the duty ratio at a fixed lamp current(I_L) of 140 mA and at the frequency of 50 kHz for the two kinds of back chassis, metal and glass plates. The luminance is an average value from 9-point measurements on the diffuser plate. The power consumption was estimated by integrating the instantaneous power over one period divided by the period itself.

As can be seen from Fig. 1(a), V_L is almost the same for the two kinds of back chassis. V_L increases with the duty ratio but shows a sudden drop at the duty ratio of 50%. P_L, plotted in Fig. 1(b), exhibits similar trend as V_L with the change of the duty ratio. However, P_L becomes smaller by about 8 W when the Al chassis



(a) Lamp Voltage

(c) Luminance

(b) Power Consumption

(d) Efficacy

Figure 1. (a) Lamp voltage, (b) power consumption, (c) luminance, and (d) efficacy of 32" FFL at the lamp current of 140 mA and the frequency of 50 kHz.

is adopted compared to the case where glass plate is positioned below the FFL. This decrease in P_L for the case of the Al-chassis-adopted FFL backlight is related to the decrease in luminance at the same condition, as can be seen from Fig. 1(c). However, the luminance reduction seems to be small compared to the large decrease in the power consumption. This combination of the changes in the luminance and power consumption results in a higher efficacy in Al-chassis-adopted FFL backlight compared to the glass-chassis-adopted FFL backlight, which can be seen from Fig. 1(d). The efficacy η increases by approximately 2 lm/W when the glass plate is replaced by the Al plate at all duty ratios except 20 %.

As a result of all these changes, the efficacy becomes the maximum at the duty ratio of 50 %, in particular, when the Al plate is used as a back chassis. This trend is consistent with the previous report on small-size, Hg-type true FFLs [5]. At the duty ratio of 50%, the electric field created by the wall charges accumulated in the previous period is overlapped on the reversed applied voltage resulting in lower voltage and lower power consumption.

Since the RMS(root-mean-square) values of V_L and I_L are almost the same for the two backlights (Fig.1 (a) and I_L =140 mA), it is necessary to investigate the voltage and current waveforms in order to find out why P_L becomes lower and η becomes higher when the Al plate is used. Figures 2 (a), and (b) show the voltage and current waveforms measured at the condition of the duty ratio=40%, respectively. When the voltage increases from 0 V, main discharge occurs accompanied by a discharge current which decreases gradually due to the wall-charge accumulation. When the voltage returns back to zero, then a self-discharge occurs owing to the consumption of the wall charge. Therefore, we expect four discharges and thus four current peaks in one period as in tubular external electrode fluorescent lamps (EEFLs) [6]. The lamp voltage exhibits almost the same waveform irrespective of what kind of back chassis is used. However, the current waveform shows a distinct difference. The current peaks occurring at both the voltage rising and falling periods become higher and

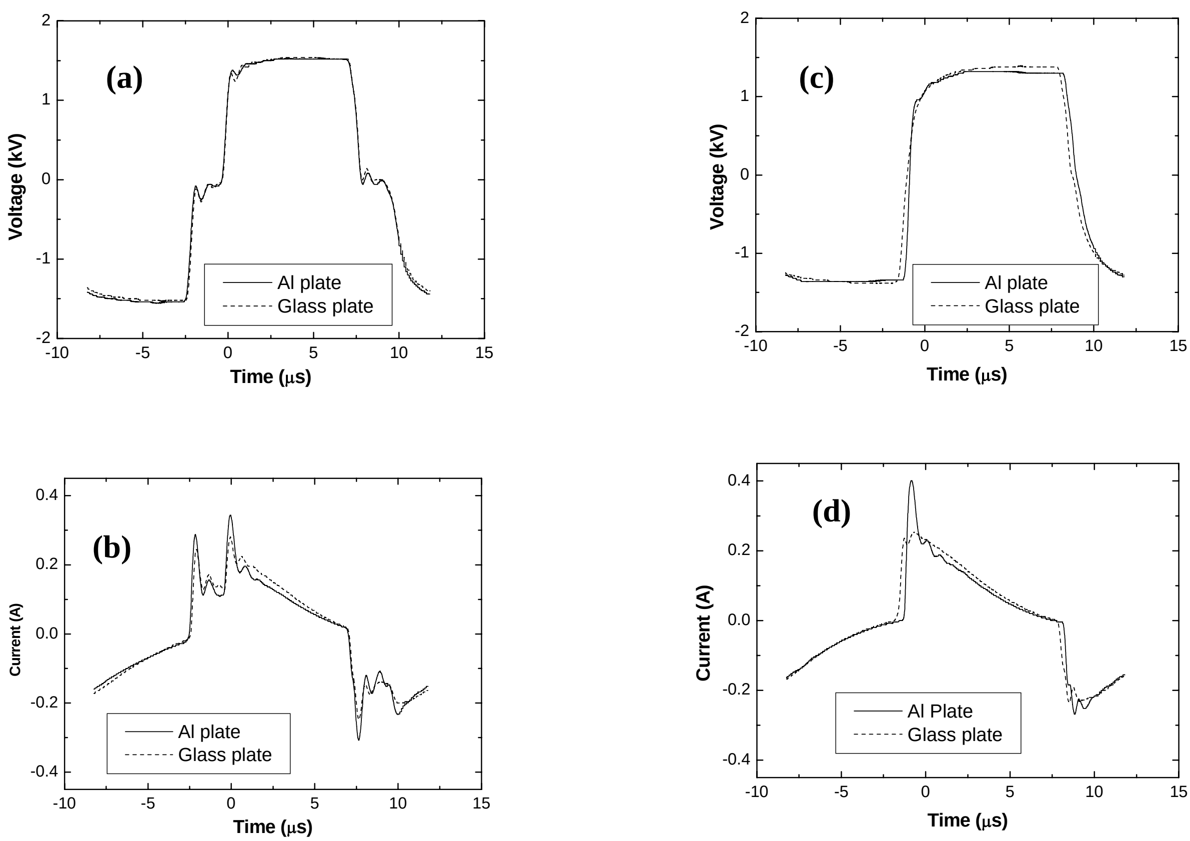


Figure 2. (a) voltage, and (b) current waveforms at the duty ratio of 40%, and (c) voltage, and (b) current waveforms at the duty ratio of 50% recorded at the fixed lamp current of 140 mA and the frequency of 50 kHz.

Sharper when the Al plate is used compared to the glass-plate-adopted backlight. In addition, current decreases faster during the voltage-on period with the Al plate positioned. Since the power consumption is estimated from the multiplication of the current and the voltage during one period, higher current during the voltage rising and lower current during the voltage-on period result in a lower power consumption detailed in Fig. 1 (b).

Figures 2 (c) and (d) show the voltage and current waveforms measured at the condition of the duty ratio=50%, respectively. The difference in the height of the current peak formed during the voltage rising period is more substantial than the case at the condition of the duty ratio=40% although the voltage waveforms are not so much different. The different height of the current peaks when the polarity changes is due to the asymmetric voltage shapes and thus the different rising times as can be seen from Fig.2 (d). All these results indicate that the existence of a nearby equipotential surface, i.e., an Al metal plate induces a strong current peak when the voltage is applied to FFL.

When the Al plate is placed beneath the FFL, the field strength in the discharge space near each electrode becomes higher because of the effect of the metal plate, which will in turn increase the electron temperature during the Townsend avalanches [7]. In contrast, the potential gradient inside the FFL would be relatively uniform when the glass plate is positioned below it instead of the metal plate. Since during the Townsend avalanches where the electron density is low the electron temperature can be controlled by the strength of the applied electric field, concentration of the electric field at both ends of FFL might induce higher electron temperature, larger current peak and stronger intensity of ultraviolet light. This seems to be the main origin of the higher efficacy observed in the Al-plate-adopted FFL backlight.

4. Summary

Electrooptic characteristics of multi-channel-structured, 32-inch, mercury-type FFLs have been investigated in various operating conditions. The lamp voltage and the power consumption decreased when the duty ratio became 50% at which the internal electric field caused by the wall charges aids the ignition of the main discharge when the polarity of the external voltage is changed. The highest efficacy was thus achieved at this condition.

The adoption of the metal plate as a back chassis of the backlight lowered the power consumption and increased the current peak occurring at the voltage rising compared to the case of the glass-plate-adopted FFL. Field concentration near the electrodes seems to increase the electron temperature and the intensity of the ultraviolet light during the Townsend avalanches resulting in higher efficacies.

5. References

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