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Study on the Luminance Properties of Optical Films for Flat-lamp Backlight Applications

Mi-Yeon Yu, Ji-Hee Park, and Jae-Hyeon Ko*

Department of Physics, Hallym University, Chuncheon, Gangwondo, 200-702, Korea

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The luminance properties of FFL(Flat Fluorescent Lamp) backlights have been investigated in detail for the first time. The on-axis luminance gain as well as viewing-angle characteristics on various combinations of optical films were obtained from FFL backlight and compared to the results of conventional CCFL(cold-cathode fluorescent lamps) backlights. It was found that the on-axis luminance gains achieved by using optical films in the FFL backlight were lower than those in the CCFL backlight indicating that the recycling processes occurring between optical films and light sources/reflection sheet are not so effective in the FFL backlight due to the much larger area of, and thus higher absorption probability of the FFL. This result suggests that new optical films should be developed for FFL backlight and other flat-lamp backlight technologies.

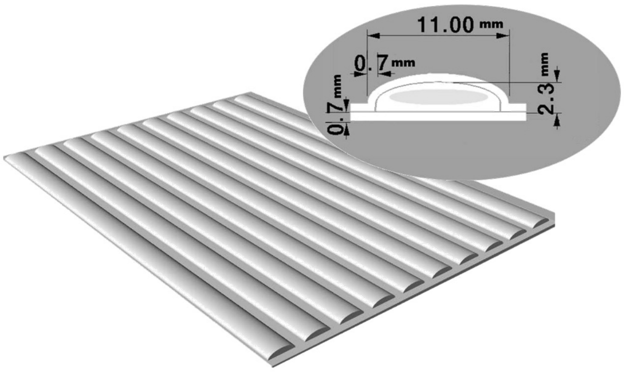
Keywords: Flat Fluorescent Lamp (FFL), backlight unit (LCD), Luminance gain, angular distribution, liquid crystal display (LCD)

OCIS codes : (120.2040)Displays ; (150.2950) Illumination ; (230.3720) Liquid-crystal devices

A backlight unit (BLU) is an illumination device used for the non-emissive liquid crystal display (LCD). BLU consists of light sources and several kinds of optical components. The overall device performance of BLU is determined by the combination of these two parts. Several light sources have been adopted and are under development for BLU, such as cold-cathode fluorescent lamps (CCFL), external-electrode fluorescent lamps (EEFL), flat fluorescent lamps (FFL), light emitting diodes (LED), etc [1]. Among these, FFL BLU has recently attracted great attention owing to its structural simplicity and superior brightness uniformity compared to the conventional tubular fluorescent lamps. The most typical FFL from the viewpoint of commercialization is a mercury (Hg)-type multi-channel-structured FFL since it is characterized by several advantages such as a high light-generating efficiency as well as an easy manufacturing process [2]. In addition to the unique advantages of FFL itself, optimized combination of optical films for the FFL is prerequisite to maximize the overall performance of FFL BLU. However, there has been no report on the detailed optical characteristics, i.e., the luminance gain and the viewing-angle properties of FFL BLU till now. The purpose of this letter is to report detailed luminance properties on various combinations of optical films put over an FFL BLU and thus to clarify the necessary conditions from which the device performance of an FFL BLU can be maximized.

The detailed structure of FFL used in the present study is described in Ref.[3]. It is a 32-inch Hg-type FFL consisting of 28 channels of which the cross-sections are semi-elliptical. A schematic drawing of the Hg-type multi-channel-structured FFL with detailed dimensions of the cross-section of each channel is shown in Fig.1(a). Only 10 discharge channels are shown in this schematic figure although 28 channels are included in one 32-inch FFL. Fig. 1(b) is a picture of the FFL backlight used in the present study. In order to investigate the effect of optical films on the light-output distribution from the light source, conventional optical sheets have been put over the FFL at a certain distance. These films are a diffuser plate (DP), a diffuser sheet (DS), a one-dimensional prism film (BEF II from 3M, abbreviated as BEF), and a reflective polarizer (DBEF-D from 3M, abbreviated as DBEF). The angular distribution of the luminance on each film has been measured by using either the EZ-contrast of ELDIM or the luminance colorimeter (BM-7, TOPCON). For comparison, the light

*Corresponding author: hwangko@hallym.ac.kr



(a)

(b)

FIG. 1. (a) A schematic drawing of the Hg-type multi-channel-structured FFL with detailed dimensions of the cross-section of each channel. Only 10 discharge channels are shown although 28 channels are included in one 32-inch FFL. (b) A picture of the FFL backlight used in the present study.

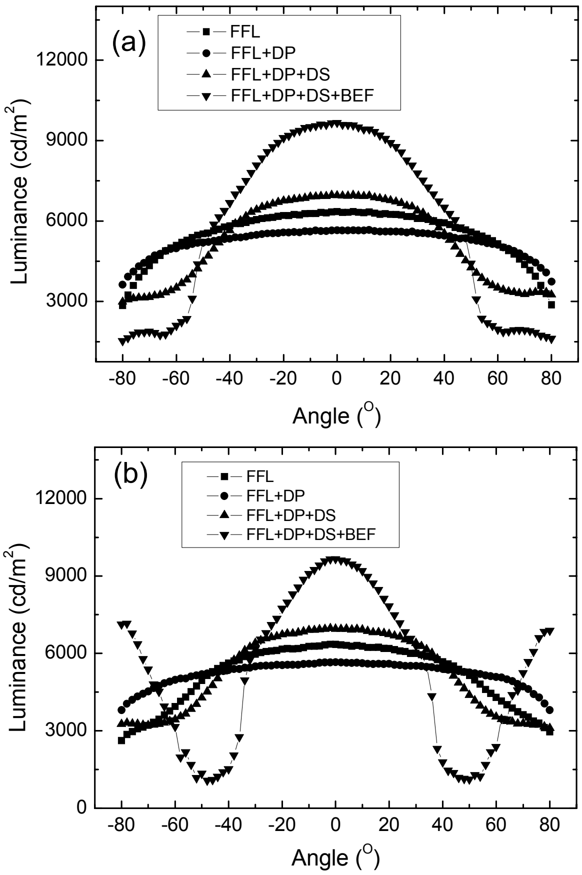


FIG. 2. The angular distribution of the luminance on the viewing angle along both (a) parallel(horizontal) and (b) perpendicular(vertical) directions with respect to the one-dimensional horizontal grooves of the prism film.

output distribution on a CCFL BLU has also been investigated by the same method. The on-axis luminance on each optical film has been obtained for the two backlights from both BLU and "BLU+panel" combination. Commercially-available 32-inch LCD TV (Samsung Electronics) has been used for this measurement. In case of EEFL, published data from Ref. [4] will be compared to the results of CCFL and FFL backlights.

Figures 2 (a) and (b) show one experimental result for the angular distribution of the luminance on viewing angle along both parallel (horizontal) and perpendicular (vertical) directions with respect to the one-dimensional horizontal grooves of the prism film. It should be noted that the direction of multi channels of FFL is also the same as that of the prism grooves of BEF. The light-output distribution on the FFL was measured from the center point of one channel. All the emitted lights are homogenized via DP on which the angular distribution of the luminance is almost Lambertian, i.e., showing almost the same luminance irrespective of the viewing angle. If DS is put on DP, the on-axis luminance increases while the viewing angle becomes narrower due to the collimating function of the spherical beads attached on the PET substrate of DS. On BEF, the emitted light from DS is collimated only along the vertical direction because of the one-dimensional collimating nature of the prism film [5]. If the reflective polarizer (DBEF) is inserted between the backlight and the LCD panel, the polarization component perpendicular to the transmission axis of the bottom polarizer of the LCD panel, which would otherwise have been absorbed by the polarizer, will be reflected downward and recycled via transformation of the polarization state resulting in the increase of the brightness of the LCD panel. However, the apparent luminance on the DBEF without LCD panel will be reduced compared to the value on BEF because a DBEF transmits only one polarization component between the two orthogonal polarization states. All these results about luminance distribution on FFL backlight are similar to those obtained from CCFL backlight [6].

Table 1 shows the relative on-axis luminance gain on each optical film of CCFL, Hg-type FFL, and EEFL backlights. The relative change in the panel luminance is also shown for the CCFL and FFL backlights. It can

TABLE 1. The relative change in the on-axis luminance gain obtained from CCFL, Hg-type FFL, and EEFL backlights for each combination of optical films. Relative changes in the panel luminance are also shown for the CCFL, and FFL backlights.

Combination of optical films	32-inch CCFL Backlight (3 f[a], 16 ea[b])		32-inch Mercury-type FFL Backlight		32-inch EEFL Backlight[c] (4 ϕ[a],18 ea[b])
	Backlight	Panel	Backlight	Panel	Backlight
DP	100%	100%	100%	100%	100%
DP+DS	130%	126%	124%	120%	115%
DP+DS+BEF	197%	183%	183%	165%	133%
DP+DS+BEF+DBEF[d]	(134%)	237%	(118%)	209%	78%

[a] outer diameter of CCFL/EEFL
[b] the total number of lamps included in the backlight
[c] Data taken from Ref. [4].
[d] DP=Diffuser Plate, DS=Diffuser Sheet, BEF=prism film, DBEF=reflective polarizer

be noticed that in the CCFL backlight the on-axis luminance gains achieved by using DS and DS+BEF are 30% and 97%, respectively. However, the same combinations of optical films give the luminance gains of 24% and 83%, respectively, in case of FFL backlight. The values of the relative change in the on-axis gain measured on the LCD panel between the two types of backlight show similar behaviors. The relative increase in the on-axis luminance of LCD panel is lower than that of BLU with the same combination of optical films, which may be due to scattering effects occurring in the LCD panel. The on-axis luminance gain of EEFL backlight is much lower than the other two backlights. This result is very strange because the structure and optical properties of EEFL are almost the same as those of CCFL, and the origin of this large difference in the optical performances remains unclear at the moment.

The smaller luminance gain of FFL backlight compared to CCFL backlight can be understood if the optical process by which the performances of optical films are achieved is considered. Part of the upward rays from the light source toward the optical films are reflected downward at the interfaces and diffusely reflected back from various components of BLU such as light sources, the reflection sheet, and other optical films toward LCD for recycling. Changes in the direction of rays and the polarization state are particularly important for the luminance gain of the prism sheet and the reflective polarizer, respectively. In this respect, high reflectance on various parts comprising BLU for the downward rays is a very important condition for effective recycling and high luminance gain. Since FFL covers all the area of backlight and its area is much larger than that of tubular lamps in CCFL backlight, more rays are tend to meet and absorbed by the FFL rather than to be reflected back towards the optical films for the recycling process. Due to this fact, the recycling effect of optical films included in the FFL backlight is expected to be less effective compared to the case of CCFL backlight, which is supported by the results summarized in Table 1.

The present study suggests that new optical films should be developed for FFL-backlight applications because conventional films are optimized for effective recycling processes occurring between films and the light sources and the reflection sheet. High reflectance and low absorption are important conditions for effective recycling. In case of FFL backlight, optical films should transform the upward rays into desirable ones for luminance gain at a single pass instead of using cumulative recycling processes since the absorption probability of rays by FFL is expected to be larger as rays meet FFL more often during the recycling processes when the conventional films are used. The results presented in this study may serve as important data sets for the development of new optical films unique for FFL-backlight applications since the effect of the lamp structure on the recycling processes as well as detailed viewing -angle characteristics of FFL backlights have been revealed for the first time in this letter. This suggestion can also be applied to other flat lamps such as field-emission lamps, OLED (organic light emitting diode)-based white lamps, etc. Simulation methods based on the ray-tracing technique may be helpful for the development of optical films for FFL backlight [7-8].

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