Optical performances of flat-lamp backlights for LCD applications

Jae-Hyeon Ko, Mi-Yeon Yu
Dept. of Physics, Hallym University, Chuncheon City, Gangwondo, Korea
Phone: 82-33-248-2056, E-mail: hwangko@hallym.ac.kr.

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Abstract

The on-axis luminance gain as well as the viewing-angle characteristics of flat-lamp-based backlights have been analyzed for the first time. The on-axis luminance gain on each optical film in flat-lamp backlight was smaller than that obtained from the conventional tubular-lamp-based backlight. The origin of and possible solution to this problem were suggested.

1. Introduction

Recently, new light sources for LCD backlight have attracted great attention due to the possibility of achieving cost reduction and technological innovation[1]. Flat lamps are one of the new light sources, which may be categorized into mercury or xenon-type flat fluorescent lamps (FFLs)[2-3], field-emission lamps[4], organic or inorganic-emission-type flat lamps[5] according to their lighting principles. Since the flat lamp comprises a single light source in the LCD backlight, it may be used to reduce the number of components included in the backlight and thus to innovate the backlight technology. However, detailed optical performances of flat-lamp backlight have not yet been studied systematically and reported till now. The present study reports various optical performances of two kinds of flat-lamp backlights, including viewing-angle characteristics, luminance gains on each optical film and their comparison with those of conventional tubular backlights such as CCFL(cold-cathode fluorescent lamp) backlight. In particular, the correlation between the structure of the light source and the optical performances of various optical films will be analyzed in detail.

2. Experimental

Mercury(Hg)-type multi-channel-structured FFL backlight was fabricated according to the way described in Ref.[6]. It is a 32-inch backlight having 28 parallel channels. Xenon(Xe)-type FFLs have been fabricated according to the conventional processes [7]. This FFL was made by using two flat sodalime glasses of which the thickness was 2 mm and the area was 50*80 mm^2. The discharge gap between the two glasses was 1 mm, and the discharge space was filled with a Ne-Xe(5%) mixture at a pressure of 100 torr. Two Cu mesh electrodes with a pitch of 300 μm and a line width of 10 μm were attached on both outer surfaces of flat glasses for igniting and maintaining uniform discharges. In order to investigate the effect of optical films on the light-output distribution, conventional optical films have been put on the FFL, a diffuser plate(DP), a diffuser sheet(DS), a one-dimensional prism film (BEF II from 3M), and a reflective polarizer (DBEF-D from 3M). The angular distribution of the luminance on each film has been measured by using either a EZ-contrast of ELDIM or a luminance colorimeter (BM-7, TOPCON). For comparison, light output distribution on CCFL backlight has also been investigated by the same method. The on-axis luminance on each optical film has been obtained for the CCFL and Hg-type FFL backlights as well as for the combination of backlight and LCD panel. Commercially-available 32-inch LCD TV (Samsung Electronics) has been used for this measurement. In case of EEFL(external electrode fluorescent lamp) backlight, published data from Ref.[8] will be compared to the results of CCFL and FFL backlights.

3. Results and discussion

The angular distribution of the luminance on each optical film in the 32-inch Hg-type FFL backlight was measured along the horizontal and vertical directions. The FFL used in the evaluation was multi-channel type of which the structure was described in Ref.[6] in detail. Figures 1 (a) and (b) show the result for the 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 formed on FFL is also the same to that of the prism grooves on BEF. The light-output distribution on the FFL was measured on the center point of one channel. All the emitted lights from the lamp are homogenized via multiple refraction and reflection in DP over which the angular distribution of the luminance is almost Lambertian. If DS is put on DP, the on-axis luminance increases while the viewing angle becomes narrower compared to the Lambertian distribution because of the collimating function of the spherical beads attached on the PET substrate of DS. On the prism film, the emitted light from DS is collimated only along the vertical direction owing to the one-dimensional collimating nature of the prism film [9].

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 change in the polarization state to the orthogonal one, resulting in the increase of the brightness on the LCD panel. However, the apparent luminance on DBEF without LCD panel will be reduced compared to the value on BEF because DBEF transmits only one polarization component between the two orthogonal polarization states of the incident lights coming from lower optical films. Overall characteristics about the luminance distribution on FFL backlight are similar to those obtained from CCFL backlight [10]. From the above discussions, it is clear that recycling of the light via appropriate transformation of the direction and the polarization state into desirable ones is very important for achieving high on-axis luminance [11].

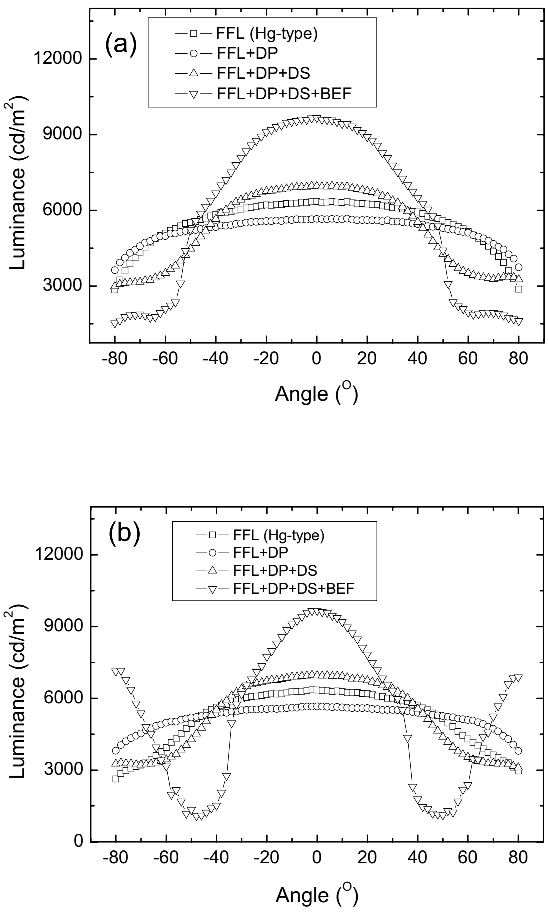

Fig. 1. The angular distribution of the luminance on each optical film of 32-inch Hg-type FFL along (a) horizontal and (b) vertical directions [11].

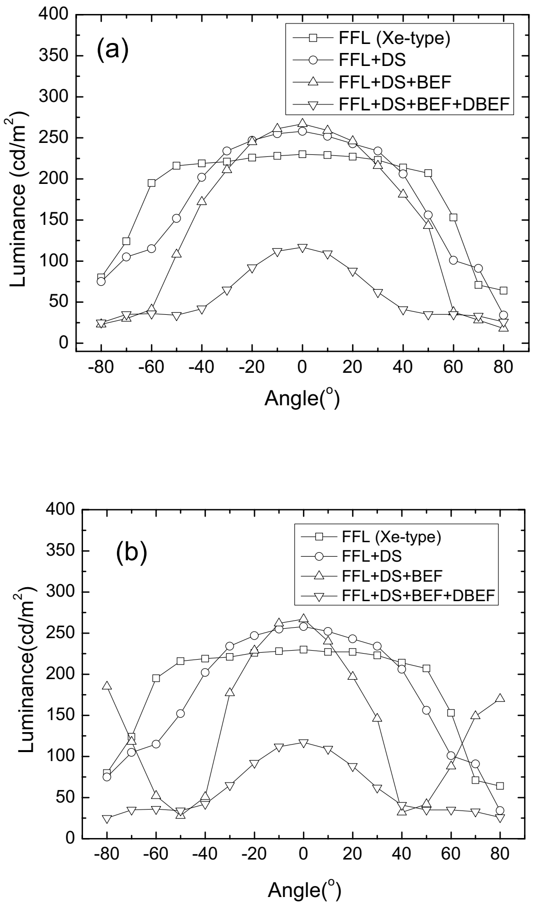

Fig. 2. The angular distribution of the luminance on each optical film of Xe-type FFL along (a) horizontal and (b) vertical directions.

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

Combination of optical films	32-inch CCFL Backlight (3 ϕ[a], 16 ea[b])		32-inch Hg-type FFL Backlight		32-inch EEFL Backlight[c] (4 ϕ[a],18 ea[b])	Xe-type FFL Backlight	
	BLU	Panel	BLU	Panel	Backlight		BLU
DP	100%	100%	100%	100%	100%	L(=FFL)	100%
DP+DS	130%	126%	124%	120%	115%	L+DS	112%
DP+DS+BEF	197%	183%	183%	165%	133%	L+DS+BEF	116%
DP+DS+ BEF+DBEF	(134%)	237%	(118%)	209%	78%	L+DS+BEF +DBEF	(51%)

a) outer diameter of tubular lamps (in mm)
b) the total number of lamps included in the 32-inch backlight
c) data taken from Ref.[8]

Figure 2 shows the dependence of the luminance on the viewing angle on each film included in the Xe-type FFL backlight. It can be seen from Fig.1 and 2 that the on-axis luminance gains on the optical films in FFL backlights are inferior to those achieved from typical tubular CCFL backlight. In particular, luminance gains of optical films in Xe-type FFL backlight are much lower than those of CCFL and Hg-type multi-channel-structured FFL backlights. All the obtained results on three types of backlights in addition to those on the EEFL backlight, of which the data were taken from Ref.[8], have been compared in Table 1. The relative change in the on-axis luminance on the LCD panel is also shown for the CCFL and Hg-type FFL backlights. The on-axis luminance gains achieved by using DS and DS+BEF in the CCFL backlight are 30% and 97%, respectively. However, the same combinations of optical films bring about the luminance gains of 24% and 83%, respectively, in case of Hg-type FFL backlight. These values reduce to only 12% and 16% in case of Xe-type FFL backlight. In particular, the luminance increase due to the prism film is surprisingly small compared to other two backlights. Similarly, the on-axis luminance gain of EEFL backlight[8] is much lower than those values obtained from the CCFL and Hg-type FFL backlights. This result looks 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 fact that the increase in the on-axis luminance by the conventional optical films for FFL backlights is inferior to those values achieved from CCFL backlight may be understood if the optical process by which the optical performances of optical films are achieved is considered. The emitted rays from light sources go upwards and meet optical films. Part of these rays pass through the optical films toward the LCD while the other rays are reflected back downwards, which are diffusely reflected upwards for recycling. Here, the “recycling” process indicates the changes in the direction and in the polarization state of rays during the diffuse reflection, which are particularly important for the luminance gains achieved by the prism film and the reflective polarizer, respectively. Therefore, efficient recycling via high reflectance on various parts in the backlight for the downward rays is the key factor by which high luminance gains can be achieved from the optical films.

In this respect, the structure of the light source may be one of the important factors relevant to the recycling process. FFLs are composed of many layers such as two glass substrates, two phosphor layers, one reflection layer, and/or protection layers. In case of Xe-FFL, two electrode layers with adhesive layers are attached on the glass plates. On various boundaries between the layers occur reflection and scattering of rays, and absorption can possibly arise by the materials themselves comprising the layers. Since FFL covers all the area of the backlight and its area is much larger than the sum area of tubular lamps in CCFL backlight, more rays are tend to be met and absorbed by the FFL rather than to be reflected back towards optical films for 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.

The results revealed by the present study suggest that conventional films are not optimized ones for FFL backlights in which recycling process is intrinsically inferior to that occurring in CCFL backlight due to higher absorption and lower reflectance. Instead of cumulative recycling processes between optical films and light sources (and/or reflection sheet), new collimating films uniquely applicable to FFL backlights should be developed by which the upward rays from FFL can be transformed into desirable ones at a single pass. For example, diffusing layers on the diffuser plate and the diffuser sheet may be designed into a certain pattern which is correlated to the emitting structure of FFLs for obtaining higher transmittance. This suggestion can also be applied to other flat lamps such as field-emission lamps, OLED (organic light emitting diode)-based white lamps, etc.

It remains to be understood why large differences in the optical gains exist between Hg-type and Xe-type backlights as can be seen from Table 1 and Fig.1 and 2. Part of the origin for this result may be different emitting structures and different layers included in the FFLs. In addition, the present Xe-type FFL backlight seems to be too small to carry out reliable evaluation on the optical performances of optical films.

4. Summary

The present study revealed that the on-axis luminance gains achieved by optical films in the FFL backlights are lower than those in the conventional CCFL backlight due to inferior recycling process, which seems to be intrinsic due to much larger area as well as more complex layer structure of FFLs. This result suggests that optical films of new concepts should be developed for FFL-backlight applications because conventional films are not optimized ones for effective recycling process occurring between optical films and the light sources. The results presented in this study may serve as important data for the development of unique optical films for FFL-backlight applications since the on-axis luminance gain as well as detailed viewing-angle characteristics of FFL backlights have been revealed for the first time.

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