Initial Photometric and Spectroscopic Characteristics of 55-inch CCFL and LED Backlights for LCD-TV Applications

Jae-Hyeon Ko* · Jin-Sun Ryu · Mi-Yeon Yu · Seung-Mi Park · Su-Jin Kim

Abstract

For better picture quality in LCD TVs, it is important to reach a steady emitting state within as short a time as possible in the initial stage after the TV is turned on. The initial characteristics of LCD TVs are mainly determined by the properties of the backlight. In the present study, the photometric and spectroscopic properties of a 55-inch Cold Cathode Fluorescent Lamp (CCFL) and Light Emitting Diode (LED) backlights were investigated. The measured properties include time dependence of the spectrum, luminance, and color coordinates. The results show that the change in the spectroscopic properties of the LED backlight is smaller than that of the CCFL backlight. This indicates that the initial picture quality of the LCD TV with the LED backlight is superior to that with the CCFL backlight. The origins of this difference were discussed in relation to the inherent characteristics of the two light sources.

Key Words : LCD TV, CCFL backlight, LED backlight, LED TV, spectroscopy

1. Introduction

Recently, the “LED TV” has attracted great attention due to its super-slim form factor and low power consumption. The LED TV is one of the Liquid Crystal Display (LCD) TVs in which an LED backlight has been adopted. Depending on the location of the LED, the LED backlight can be labeled as either direct-lit or edge-lit. LED is a point light source and thus needs a rather complex optical structure for the transformation of the emitted light from the LEDs into the two-dimensional homogeneous flat light source. In addition, color mixing might be another technological issue of the LED backlight if tri-color LEDs are used for a better color gamut instead of white LEDs [1].

Traditionally, discharge-based light sources such as CCFLs and External Electrode Fluorescent Lamps (EEFL) have been used in the backlight [2]. These fluorescent lamps normally include mercury as an element for the generation of ultraviolet (UV) photons that excite the tri-color phosphors to generate visible light. However, the vapor pressure of mercury in the lamp is very sensitive to the

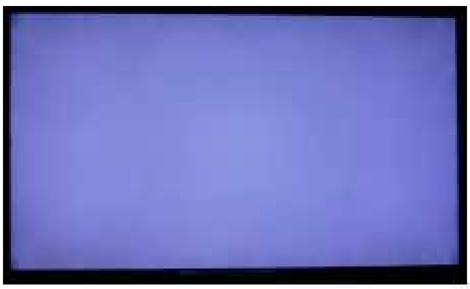
* Main author : Department of Physics at Hallym University
Tel : +82-33-248-2056, Fax : +82-33-256-3421
E-mail : hwangko@hallym.ac.kr
Date of submit : 2009. 9. 25
First assessment : 2009. 10. 15
Completion of assessment : 2009. 11. 19

ambient temperature [3]. This property affects the initial characteristics of the backlight and thus the initial picture quality of the LCD TV. The present study aims to investigate and compare the initial photometric and spectroscopic characteristics of LED and CCFL backlights, which will serve as basic, important data for further improvements of these backlights.

2. Experiment

The 55-inch LED backlight used in this study is the edge-lit type. 372 white LEDs are located at the four sides of the light guide plate (LGP), on which a diffuse sheet (PTR873 from Shinwha Intertek), a prism sheet (UTE32D from MNTECH) and a reflective polarizer (DBEF from 3M) are placed sequentially to enhance luminance on the backlight.

(a)



(b)

Fig. 1. (a) white LED at the edge of the LED backlight; (b) the emitting condition of the LED backlight

Figures 1 (a) and (b) show the picture of the aligned white LEDs and the emitting condition of the LED backlight.

The CCFL backlight includes 28 CCFLs of which the diameter is 4 mm. Over the light sources, the diffuser plate, the diffuser sheet, the prism sheet and the DBEF are placed.

For the exact measurement of the spectrum, luminance and color coordinate, a spectroradiometer (PR670, Photo Research) was used. The luminance uniformity as well as the viewing-angle characteristics were investigated on each optical component according to conventional standards. In order to discard any extrinsic effect on the measurement, the experiment was carried out at the same room temperature of 25[℃]±1[℃]

3. Results and Discussion

3.1 Basic Optical Properties

In order to investigate basic optical properties, the luminance, the viewing-angle characteristics, and the emitting spectrum were measured from the two backlights after they had been aged for at least one hour. The luminance uniformity on each backlight obtained from 9-point measurements, which is defined as L_{min}/L_{max} where L_{min} and L_{max} are the lowest and the highest luminance values measured, are approximately 90[%] and 94[%] for the LED and CCFL backlights, respectively. These results suggest that the uniformity property of the LED backlight is comparable to that of the CCFL backlight.

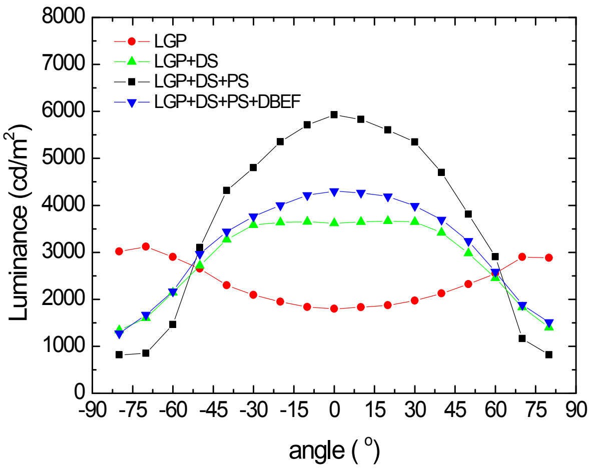


Fig. 2. The angular distribution of the luminance on each film of the LED backlight (DS; diffuser sheet, PS; prism sheet, DBEF; reflective polarizer)

Figure 2 displays the angular distribution of the luminance on each optical component of the LED backlight measured along the horizontal direction. LGP guides the incident light from the LED and redirects it toward the LCD panel via scattering dots printed on the backside of the LGP. The reflecting property of the scattering dots includes both specular and diffuse characteristics, which tends to direct the escaped light toward high angles as can be seen in Figure 2. The diffuser sheet and the prism sheet on the LGP have the functions of redirection and collimation acting on the inclined rays from the LGP which are attributed to refraction at the microlenses located on the upper surfaces. The on-axis luminance increases while the viewing angle decreases due to these effects. However, the optical function of the reflective polarizer is realized when the LCD panel is attached to the backlight because the reflective polarizer recycles the specific polarization component orthogonal to the transmission axis of the bottom polarizer of the LCD panel. This is the reason that the apparent luminance on the DBEF without LCD is lower than that on the prism sheet.

Figure 3 exhibits the emitting spectrum of two backlights in the visible range measured after the backlights have been aged. The spectrum of the CCFL backlight is the typical one of fluorescent lamps. It consists of broad spectral features due to the tri-color phosphors superposed on the sharp visible lines from the mercury atoms. Compared to normal fluorescent lamps for general lighting, the portion of the short-wavelength region is larger, resulting in the blue-shifted color temperature, which is suitable for TV applications. The spectrum of the LED backlight comprises a sharp peak at ~ 445 nm due to the blue chip and two broad peaks emitted from the green and red phosphors in the resin surrounding the LED chip. This combination is more favorable from the viewpoint of color reproduction compared to the conventional white LEDs consisting of one blue LED chip and yellow phosphors.

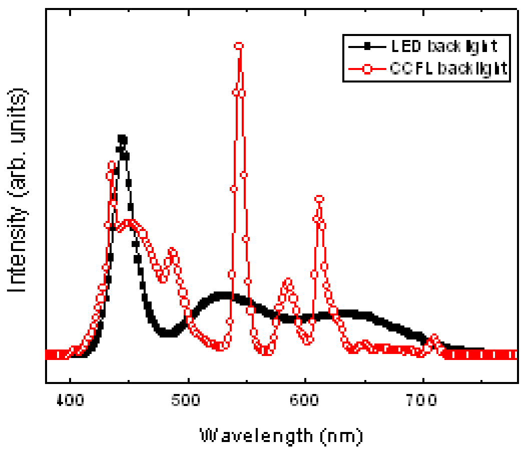


Fig. 3. The emitting spectra of CCFL and LED backlights in the visible range

3.2 Initial Photometric and Spectroscopic Characteristics

Initial characteristics of the backlight are very important for the picture quality of LCD TVs. In the present study, the time dependence of luminance, color coordinates and spectrum were investigated. Figures 4 (a) and (b) are the time dependence of the luminance (L) of the CCFL and LED backlights, respectively. The luminance of the CCFL backlight is low at the instant it is turned on. It rapidly increases over time and becomes saturated when the time reaches approximately 20 minutes. In contrast, the luminance of the LED backlight is highest when it is turned on and then decreases over time. Beyond 40 minutes, the luminance does not change significantly. Apparently, the luminance of the LED backlight seems to be saturated for a longer period compared to the CCFL backlight. However, the relative change in the luminance of the CCFL backlight is much greater than that of the LED backlight. Figure 4 (c) shows the relative change in luminance of both backlights.

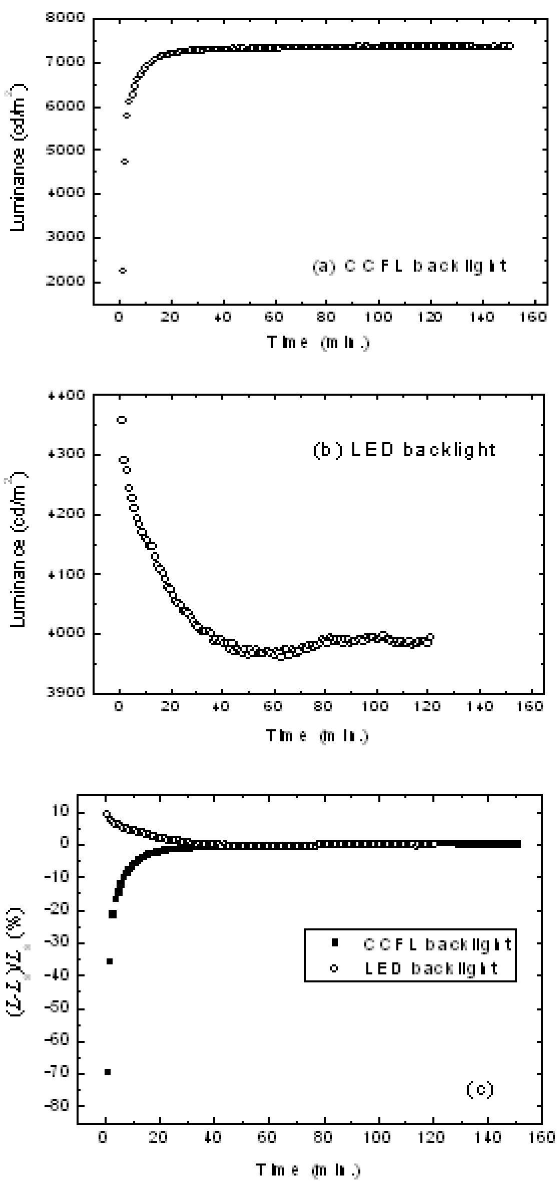


Fig. 4. The time dependence of the luminance of (a) CCFL backlight and (b) LED backlight, and (c) the relative change in the luminance of both backlights

In Fig. 4(c), L_s is the saturated luminance value obtained at the longest measurement time. As can be seen, the relative change in the luminance in the first 40 minutes is about 70[%] and 9 [%] for CCFL and LED backlights, respectively. This indicates that the initial change in the luminance of CCFL backlight is much greater than that of the LED backlight, degrading the picture quality of the CCFL-based LCD TV in its initial stage.

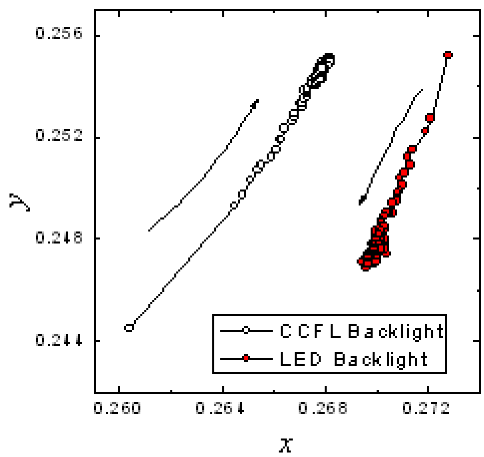


Fig. 5. The change in color coordinates (x, y) plotted on the chromaticity diagram

Figure 5 shows the change in the color coordinates (x, y) plotted on the chromaticity diagram. The arrows indicate the direction of increasing time. The change in color coordinates of the CCFL backlight is (△x=0.008, △y=0.01), which is larger than the values of the LED backlight, i.e., (△x=-0.003, △y=-0.007).

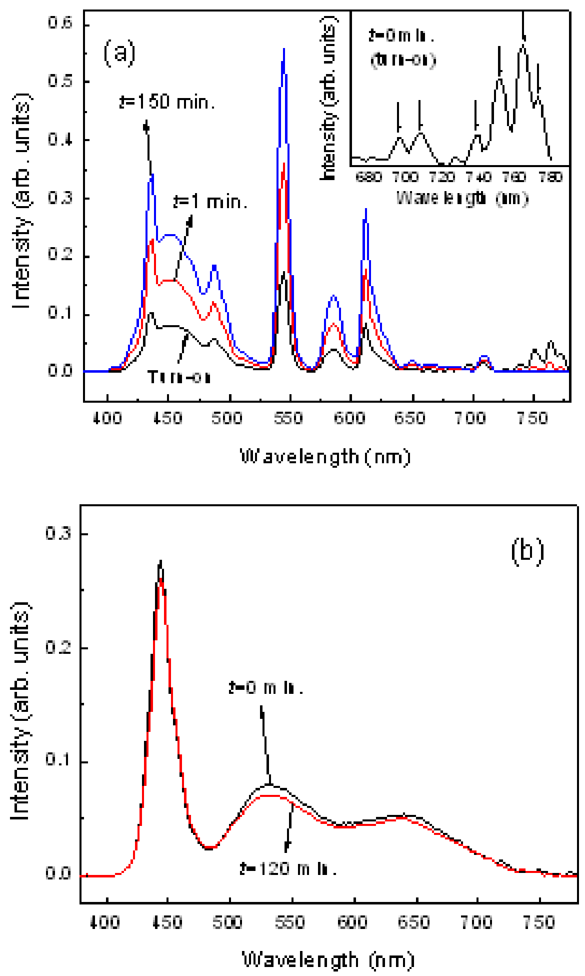


Fig. 6. The time dependence of the spectrum of (a) CCFL backlight and (b) LED backlight (The inset; the extended view of the CCFL spectrum in the near-infrared range)

The above results suggest that the lighting conditions of the two light sources change over time, and this change is more substantial in the case of CCFL. In order to scrutinize this difference, the time dependence of the spectrum was measured for both backlights. Figures 6 (a) and (b) exhibit the spectra of the CCFL and the LED backlights, respectively, at selected times.

The intensity of the spectrum of the CCFL backlight changes markedly over time in the initial stage, but the intensity as well as the spectral shape of the LED backlight does not change substantially during the first 2 hours of operation. In addition, the spectrum of the long-wavelength range (680 – 780 nm) of the CCFL backlight shows several peaks at the instant of being turned on, as can be seen from the inset of Figure 6 (a). The peak positions are consistent with the emission lines of the argon atom [4]. This indicates that the argon atoms are activated in CCFL when the lamps are turned on. The discharge condition of mercury-based fluorescent lamps is very sensitive to the ambient temperature because the vapor pressure of the mercury atoms changes very rapidly with the temperature [3]. The buffer gas in the CCFL is usually a mixture of argon and neon atoms (Ne:Ar=90[%]:10[%] in the present case). When the CCFL is turned on, there are not enough mercury atoms, and the argon atoms are ionized and excited instead of the mercury. This is the reason that the argon emission lines are strong at the initial stage and then disappear over time. As the temperature rises in the backlight, the vapor pressure of mercury rises steeply and then contributes to the discharge as well as the generation of the ultraviolet photon. According to the activation of mercury with temperature and time, the luminance of the CCFL backlight increases rapidly during the first few minutes after being turned on.

On the other hand, the junction temperature of the LED increases over time after the LED backlight is turned on. As is well known, the luminous efficacy decreases with the junction temperature because the recombination probability decreases [5]. Therefore, the luminance of the LED backlight decreases slightly due to this temperature effect.

4. Conclusion

The initial photometric and spectroscopic characteristics of 55-inch CCFL and LED backlights were investigated and compared. The uniformity property and the viewing-angle property were comparable to each other. The changes in the luminance and the color coordinates occurring in the initial stage after being turned on were much more substantial in the CCFL backlight than in the LED backlight. This result indicates that the initial picture quality of the LCD TV based on the LED backlight is expected to be superior to that of the CCFL backlight. According to the measurement of the time dependence of the emitting spectrum, significant changes in the photometric and spectroscopic properties of the CCFL backlight are due to the active excitation and ionization of the argon atoms in the CCFL in the initial stage when there are not enough mercury atoms due to the low temperature.

References

〔1〕 K. Kakinuma, "Technology of Wide Color Gamut Backlight with Light-Emitting Diode for Liquid Crystal Display Television", Jpn. J. Appl. Phys., Vol.45, No. 5B, pp. 4330-4334, 2006.
〔2〕 Jae-Hyeon Ko, "Recent Research Trends in the Development of New Light Sources for the Backlight Unit of Liquid Crystal Display", Asian J. Phys., Vol.14, No 3/4, pp. 231-237, 2005.
〔3〕 J. F. Waymouth, Electric Discharge Lamps, The M.I.T. Press, pp. 11-46, 1971.
〔4〕 http://physics.nist.gov/PhysRefData/ASD/index.html
〔5〕 E. F. Schubert, Light-Emitting Diodes, Cambridge, 2007.

Biography

Jae-Hyeon Ko

Jae-Hyeon Ko was born in 1968. He was awarded a Doctoral degree in Physics at the Korean Advanced Institute of Science and Technology in 2000. Now he is a professor in the Department of Physics at Hallym University.

Jin-Sun Ryu

Jin Sun Ryu was born in 1985. She was awarded a Bachelor's degree in Physics at Hallym University in 2009. Now she is a full-time intern in the Department of Physics at Hallym University.

Mi-Yeon Yu

Mi-Yeon Yu was born in 1985. She was awarded a Bachelor's degree in Physics at Hallym University in 2008. Now she is a Master-course student in the Department of Physics at Hallym University.

Seung-Mi Park

Seung-Mi Park was born in 1985. She was awarded a Bachelor's degree in Physics at Hallym University in 2007. Now she is a Master-course student in the Department of Physics at Hallym University.

Su-Jin Kim

Su Jin Kim was born in 1988. She is a Bachelor-course student in the Department of Physics atHallym University.