Colorimetric Characteristics Evaluation of OLED and LCD

Ye Seul Baek[*1], Hong Suk Kim[1], Seung Ok Park[1], Youn Jin Kim[2,3]*
[1]Dept. of Physics, University of Daejin, Pocheon, Gyeonggi , Korea
[2]Dept. of Colour Science, University of Leeds, Leeds LS2 9JT, United Kingdom
[3]Now with Digital Printing Division, Samsung Electronics, Suwon, Korea
Phone: +82-(0)10-4140-6963, E-mail: yeseul@daejin.ac.kr

Keywords : OLED, LCD, Colorimetric Characteristics

Abstract

In this study, colorimetric characteristics of a 2.2-inch iriver MP4 based upon OLED was evaluated and compared with another MP4 based upon Liquid Crystal Display (LCD). According to IEC61966-4, the two displays were tested in terms of spectral power distribution, tone reproduction curve (TRC), luminance, contrast, correlated color temperature, 2D color gamut and spatial uniformity. Consequently, the OLED showed better performance for the first four aspects but a similar quality was observed for the rest.

1. Introduction

Miniaturization is one of the critical issues for manufacturing portable displays. Organic Light Emitting Diode (OLED) is advantageous to miniaturization and higher-purity color reproduction so can be the most competitive candidate for the next generation portable display. In this study, colorimetric characteristics of a 2.2-inch iriver MP4 based OLED was evaluated and compared with another MP4 based upon Liquid Crystal Display (LCD). The evaluation procedure is on the basis of Kim[1] and Seime and Hardeberg.[2-3]

2. Experimental

An MP4 player, iriver Clix, on the basis of OLED was evaluated and colorimetric performance of it was compared of that of another MP4 player, iriver U10, on the basis of LCD. The resolution of this display was a Quarter Video Graphics Array (QVGA: 320 × 240 pixels) and its physical size was 2-inch diagonally. A Minolta CS-1000 tele-spectroradiometer (TSR) was used to measure luminance, chromaticity coordinates, correlated color temperature and so forth and the all measurements were performed in dark room. The measurement environment and method followed IEC 61966-4 standard[1] except for the display's warm-up time. IEC 61966-4 recommends 2 hours for typical desk-top displays but, because of the fact that portable displays are usually viewed right after switching on the power, only half an hour was allowed for the MP4s' warm-up in this study. The maximum luminance of those displays could be changed by adjusting a built-in function in their firmware. There were 3 levels of luminance that can be set: low, middle and high as given in Table 1. We selected the high level for the OLED and the middle level for the LCD so both displays show a similar luminance.

Table 1 Luminance levels that can be adjusted

Luminance (cd/m^2)	Low	Middle	High
OLED	116	142	177
LCD	92	173	236

3. Physical Evaluation

3-1. Spectral Power Distribution (SPD)

Figures 1 and 2 depict the relative spectral distributions of the two displays. The wavelength where the maximum spectral radiance is occurred for each primary of the OLED is 532nm for green and 465nm for blue. In case of the LCD, its peak wavelengths are similar to the OLED: 535nm and 460nm for green and blue, respectively. However, the peak wavelength for red is 625nm for the OLED, 590nm for the LCD. The OLED's SPD curves look sharper than the LCD's so the former may result in purer color reproduction than the latter apparently.

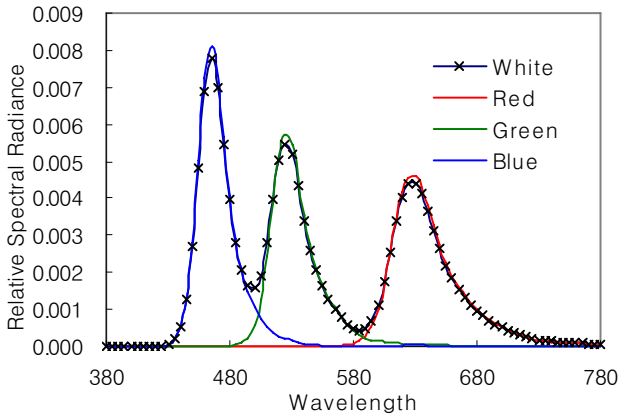

Fig. 1. Relative SPD curves of OLED

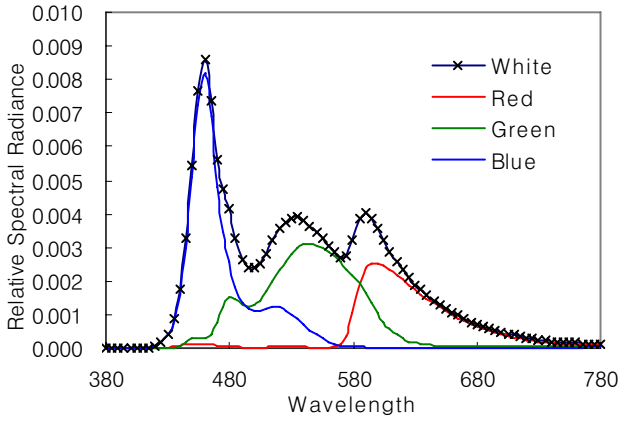

Fig. 2. Relative SPD curves of LCD

3-2. Tone Reproduction Curve (TRC)

The nine equally spaced neutral patches reproduced on the mobile LCD were measured in terms of CIE XYZ values (cd/m^2). They were then normalized according to XYZ of the white patch and plotted in Figures 3 and 4. They were typical power functions[4] but, while the red and green curves nearly overlap, the blue curve is above the other two. The power function is mathematically defined as $y=(b+ax)^{\gamma}$ where sRGB[5] recommends a γ (gamma) value of 2.2. Gamma values of the two displays used in this study were optimized using the measured nine neutral patches and were 2.21 and 2.92 for the OLED and the LCD, respectively. Gamma of the OLED was close to the sRGB.

3-3. Contrast

The maximum luminance of both displays was set to be similar (OLED: 177cd/m^2, LCD: 172.5cd/m^2) as previously introduced in Section 2 but their black levels were significantly different. It is known that typical LCD suffers the leakage light due to its own physical trait and black produces quite high luminance level. The LCD used in this study also showed a relatively higher luminance, 0.28cd/m^2, than the OLED, 0.003cd/m^2. The black level influences the contrast ratio which can be defined as the luminance ratio between black and white. The contrast ratio was 1:51000 for the OLED and 1:600 for the LCD so the former shows 85 times higher contrast ratio.

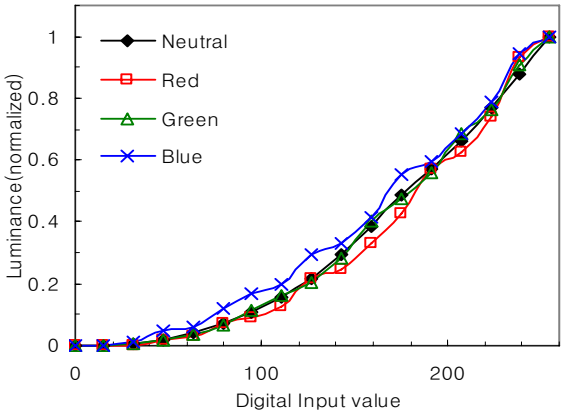

Fig. 3. Tone reproduction curves of OLED

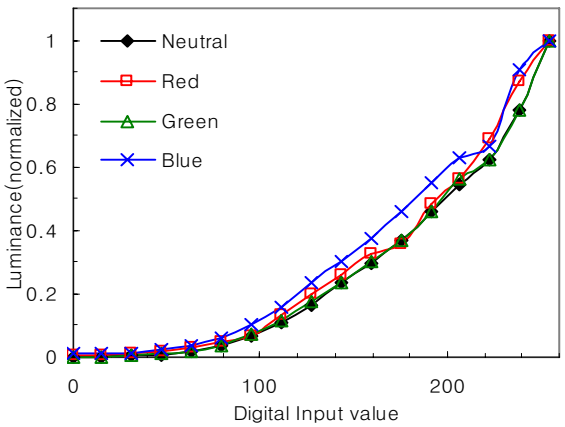

Fig. 4. Tone reproduction curves of LCD

3-4. Correlated Color Temperature (CCT)

Table 2 provides the CIE 1931 *xy* chromaticity coordinates, correlated color temperature (CCT), and *Δu'v'* for the two displays' white. CCT of the OLED was 8372 K and that of the LCD was 7180 K so the OLED produces more bluish tint. *Δu'v'* of the LCD,

0.004, was smaller than that of the OLED, 0.011.

TABLE 2. Chromaticity coordinates, CCT, and $\Delta u'v'$

	x	y	T(K)	Δu'v'
OLED	0.285	0.319	8372	0.011
LCD	0.302	0.324	7180	0.004

Figure 5 plots CCT variation across the grayscale. The solid line is for the OLED and the dotted line is for the LCD. As can be seen, variation of the solid line is much larger than that of the dotted line. Especially for the middle gray levels, CCT of the OLED is above 10000 K in general. The maximum CCT shown by the OLED reaches 17220 K at the input digital value of 47. CCT of the LCD is relatively lower compared to the OLED and its maximum was about 10000 K.

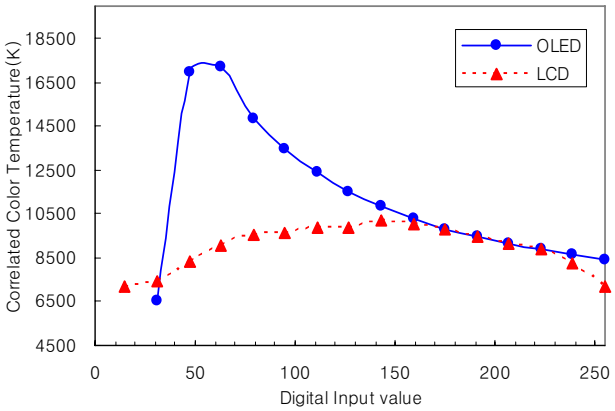

Fig.5. CCT variation across the grayscale

3-5. 2D Color Gamut

The maximum intensity of each channel was measured and plotted on a UCS diagram ($u'v'$) [6] for a comparison with sRGB[5] primaries. Figure 6 compares 2D color gamut of the two displays with sRGB, black dots, and NTSC (National Television System Committee), red dots. Note that the filled squares represent chromaticity coordinates for the OLED and empty triangles for the LCD. As can be seen, 2D color gamut of the OLED was approximately twice the LCD and 127% larger than sRGB. However, it was more or less the same as NTSC.

When chromaticity coordinates of each primary is closer to the spectral locus, its color purity becomes higher. Therefore, since the OLED's three primary colors nearly meet the spectral locus, its color reproduction purity may be a lot higher which was already expected from the sharpness of its SPD in Section 3-1.

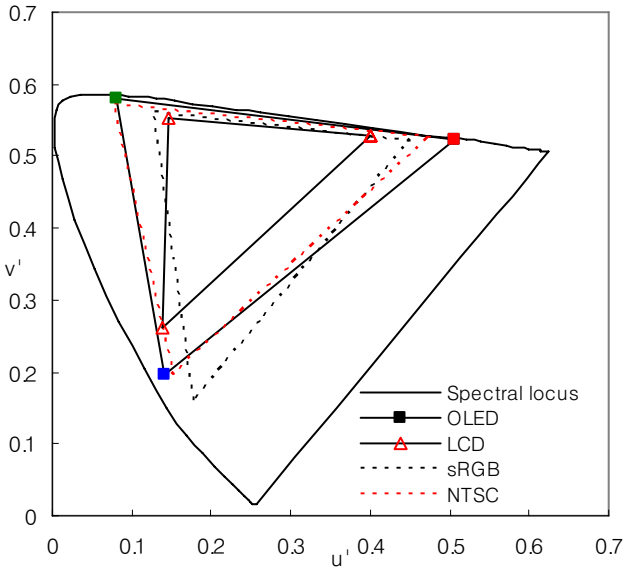

Fig. 6. 2D Color gamut of OLED and LCD

3-6. Spatial Uniformity

A white patch was displayed on the mobile LCD screen and 9 evenly distributed locations were measured. The measured CIE XYZ values were converted into CIELAB values and the difference between the centre and each location was examined in terms of ΔL^* and Δa^* b^*. For both displays, there was no large fluctuation of Δa^* b^* but the LCD only showed ΔL^* varied from 2.7 to 4.5. It might be due to the fact that LCD is based upon the backlight units located behind the panel while OLED is self-emissive.

4. Summary

In this study, OLED, which has been highlighted as a next generation display, was evaluated and its colorimetric characteristics were compared with LCD. The two displays were tested in terms of SPD, TRC, contrast, CCT, 2D color gamut and spatial uniformity. Consequently, the OLED showed a better performance for most of the characteristics but CCT of both displays was clearly fluctuated in the mid-tone levels.

5. References

1. Y. J. Kim, Developing image Quality Metrics of Liquid Crystal Displays: Internal reference Approach, university of Leeds (2007).
2. L. Seime and J. Y. Hardeberg, Characterization of LCD and DLP Projection Displays, IS&T/SID Tenth Color Imaging Conference, pp277~286 (2002).
3. IEC 61966-4, Multimedia System and Equipment-Colour Measurement and Management-Part 4: Equipment Using Liquid Crystal Display Panels (2000).
4. R. S. Berns, Billmeyer and Saltzman's Principles of Color Technology 3rd ed., John Wiley & Sons Ltd, p.165, 207-216 (2000).
5. S. Susstrunk, R. Buckley, and S. Swen, Standard RGB color spaces, Proc. IS&T/SID 7th Col. Img. Conf., 127-134 (1999).
6. R. W. G. Hunt, The reproduction of colour, 6th ed., John Wiley & Sons Ltd, p. 57,106 (2004).