Packaging technology of LEDs for LCD backlights

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Abstract: We design a package patterned with red and green emitting phosphors excited by a blue LED to emit tri-basic mixing color. For high backlight display quality, we compare several phosphors. According to our measurements, green phosphors 0752G, 0753G and red phosphor 0763R are preferred for producing a good backlight source. Compared to RGB-LED backlight units, this frame typically benefits the lighting uniformity, and can simplify the structures. It also provides higher color render and better CCT than the traditional package method of a yellow phosphor with a blue chip. However, its light efficiency needs to be further improved for the use of backlights for LCDs.

Key words: LED package; back light unit; tri-basic color; emitting phosphors; liquid crystal display; CCFL

DOI: 10.1088/1674-4926/30/7/076002 **EEACC:** 0710J

1. Introduction

An LCD (liquid crystal display) is a thin and flat display device which is made up of many color pixels arrayed in front of a backlight source. As the LCD cannot actively light itself, a form of illuminating backlight unit is needed.

A TFT (thin film transistor) LCD is a normal display device that has a sandwich-like structure with liquid crystal filled between two glass plates. Each plate TFT has as many as the number of pixels displayed, while a color filter is placed on the upper glass plate, generating RGB colors. When the liquid crystal is stimulated by an external electrical charge, it can change the properties of the light passing through it. Liquid crystals move according to the voltage between the color filter glass and the TFT glass, and the amount of light supplied by the backlight is determined by the amount of movement of the liquid crystals in such a way as to generate color[4, 5].

Traditionally, LCD backlights have been CCFLs (cold cathode fluorescent lamps). Nowadays there is a trend for people to prefer LED units to CCFLs as light resources, because of the higher LCD display quality obtained. For example, with an RGB-LED backlight, the LCD has a wider color gamut above the NTSC standard at about 110%, and a type of six-color backlight for the LCD can give a color gamut up to 150% of the NTSC specification[1]. Moreover, the LED backlight structure only needs a DC drive instead of a high voltage converter like the CCFL, thus simplifying the structure and reducing the energy consumption. This is useful for environmental protection. However, there are also some challenges such as efficiency improvement, stable ability, and heat dissipation that need to be overcome[6].

2. LED packaging technology

Usually we have three ways to form white light. The first is by using an RGB-LED mixing tri-color to form white light, and another is by using blue or UV LEDs to excite the relative kinds of phosphor and then generate tri-basic colors to mix the white light. The normal way is to use blue LEDs to excite yellow phosphors, with blue and yellow light mixing to form white light[7]. However, this method has deficiencies and its spectrum is quite different from real sunlight. We propose an idea which uses blue LEDs to excite red and green phosphors to get tri-colors for white LEDs[2, 3], as shown in Fig. 1. Through experiment, this method can achieve better color render and a relative low color temperature than the traditional way using yellow phosphor, and consistently avoid the control problem of three-color LEDs.

Traditionally, the phosphor is deposited, forming a coat on the LED chip, and excited to convert it into relative colored light, but this method has a problem with color uniformity, due to the lack of uniform deposition, and the LED shows light variations from different viewing angles. Several packaging methods have been put forward as shown below to get a uniform phosphor film for better light output.

3. Experiment and results

We choose several red and green phosphors to blend

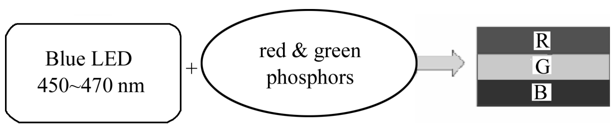

Fig. 1. A kind of new package method for white LEDs.

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Received 17 December 2008, revised manuscript received 23 February 2009

separately with epoxy resin, and then cover the blue chip in a reflector cup to package the white LED. By adjusting its thickness and solution, we can get proper emitting efficiency and better color render.

Before coating phosphors onto the blue chip, we get some epoxy resin first. Through our test, this package method gives a good light output and high efficiency. We think that epoxy resin promotes the light delivery from the LED chip, and the even phosphor distributions promise uniformity of light generation. We also tried some novel phosphors to produce higher light excitement and obtain a narrow spectrum for good color gamut. Here is the detailed experimental process:

(a) Two kinds of red phosphors and three kinds of green phosphor:

Use a blue LED chip with a wavelength $\lambda = 450$–470 nm as the exciting light source.

0751G: green light, peak wavelength $\lambda_{G1} = 505$–515 nm, approaching blue color

0752G: green light, peak wavelength $\lambda_{G2} = 515$–525 nm, near to yellow waveband

0753G: green light, peak wavelength $\lambda_{G3} = 525$–535 nm, quite similar to 0752G

0763R: generate red light with peak wavelength at $\lambda_{R1} =$ 625–635 nm

ZYP650R: red light, peak wavelength $\lambda_{R2} = 645$–655 nm, a little longer than 0763R

(b) Some phosphors blend ways with the blue-LED chip to form white light:

We use two kinds of red phosphor, separately combined with three kinds of green phosphor, and then we compare the results for better display quality.

(0) 0751G + 0752G + ZYP650R←blue light;

(1) 0751G + ZYP650R←blue light;

(2) 0752G + ZYP650R←blue light;

(3) 0753G + ZYP650R←blue light;

(4) 0753G + 0763R←blue light;

(5) 0752G + 0763R←blue light;

(6) 0751G + 0763R←blue light.

The spectral curves of our types of packaged white LEDs are shown in the figures below, measured using an integrating sphere. We also obtain varying results for the light efficiency and Ra (color render).

Figure 2 is a description of the LED packaged with three kinds of phosphors: 0751G + 0752G + ZYP650R. The curve is much closer to real sunlight than other methods, and Ra is good at 73–83, but the light efficiency is very low at about 10–20 lm/W. We think that a continuous waveband can form a spectrum much like sunlight, so the Ra result is good, but many phosphors cause low efficiency conversion, influencing the light output.

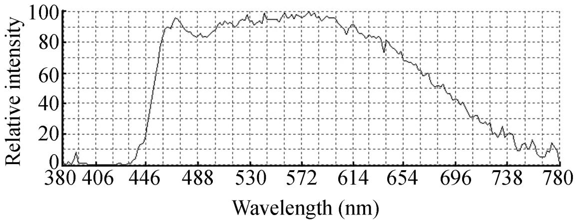

Fig. 2. Packaged spectrum with three kinds of phosphors and a blue chip.

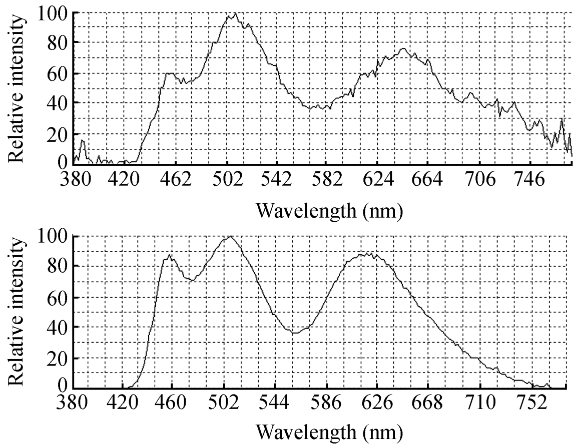

Fig. 3. Packaged spectrum using 0751 green phosphor.

In methods (1) and (6), because the 510 nm green light is quite far away from the red waveband, the middle waveband is almost lacking in the spectral curve, as shown in Fig. 3. All have low color render and also bad light efficiency, and we therefore do not consider 0751G any further.

0752G has quite similar properties to 0753G, so the figures are shown together for comparison. Throughout the measurement, the exciting efficiency is much better than that using 0751G. Also, with 0763R we obtain a better outcome than with ZYP650R, so we prefer 0763R.

For 0752G with 0763R, we get quite a good Ra of 83–89; for 0753G with 0763R, we get a high light efficiency. The output efficiency shows an almost threefold increase on the blue chip efficiency, above 30–40 lm/W, as shown in Fig. 4.

4. Conclusion

For the best quality of the white LED display for the LCD backlight, of all the phosphors used, we prefer the green phosphors 0752G and 0753G, and the red phosphor 0763R to give better color render and higher efficiency, seen in the comparison of experiment measurements.

This kind of LED unit can benefit light uniformity, and it also simplifies the backlight structure compared to the RGB-LED backlight method. The white light produced by packaging a blue chip with red and green phosphors has a higher Ra and better CCT than the traditional packaging method of a yellow phosphor with a blue chip.

When this kind of LED is used as a display light source,

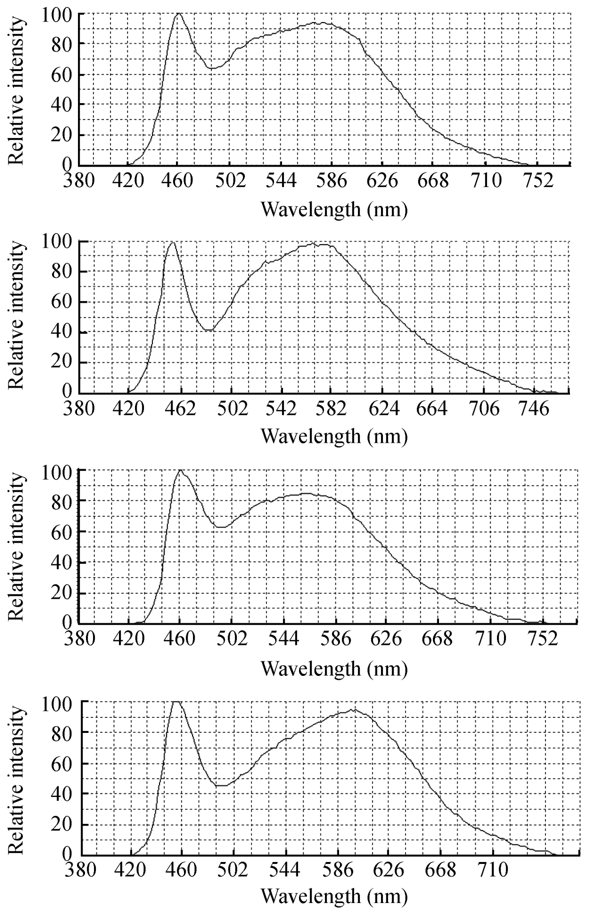

Fig. 4. 0752 and 0753 green phosphors with red phosphors.

we pay more attention to its performance parameters (such as color render and CCT) than its efficiency. As backlight units, people mostly use LEDs with low power instead of high power LEDs, for easily receiving good light uniformity and high use efficiency. We can get the power level required using this package method with a low power blue chip.

Furthermore, when used for a lighting function, high efficiency is needed. We can increase the light efficiency by choosing phosphors with good efficiency exchange capabilities, improving the packaging method, using a blue chip with high luminosity, etc.

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