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LED Backlight Module of Ultra-thin High Brightness System Design and Analysis

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Abstract: *Liquid crystal displays have many good qualities, such as ultrathinness, light weight, high brightness, and so forth. It is very important to improve the display properties of backlight module systems to provide better uniformity of brightness, lower power consumption, and lower weight. In backlight modules, the light guide plate (LGP) is a key component in reducing the cost and easier access for China to develop LGPs on its own. We have manipulated the pattern distribution of the micro features to obtain the required optical characteristics. A light guide plate (LGP) of 3.5 inch dimension using an LED light source is used as an example for the study of integrated LGPs. An integrated LGP reduces the use of optical films, which can reduce the thickness of the backlight module, increase the overall brightness, and reduce costs.*

1. Introduction

As a most widely used two-dimensional display with the highest production value, the liquid crystal display (LCD) has come to replace traditional iconoscope displays with its excellence in low energy consumption, high brightness, light weight, and fine color saturation. In the cost structure of the backlight module, the light guide plate, with a cost proportion of 17%, is second only to prismatic glasses. Among all components of the backlight module, prismatic glasses, the light guide plate, and arcatron, with a proportion of 63% in the total cost, are the most important ones. In our design of the backlight module—without any brightness enhancement film (BEF, Diffuser)—a new type of light guide plate, integrating the functions of light guide plate, diffuser plate, and prismatic glass into one, has been developed by use of reflecting surfaces and the illuminating surface of the light guide plate in a thinner structure.

2. Backlight module structure

2.1 Introduction to backlight module structure

The backlight module is comprised of six basic components, including light source, light guide plate, reflector, diffuser, brightness enhancement film, and P-S Converter (Fig. 1.).

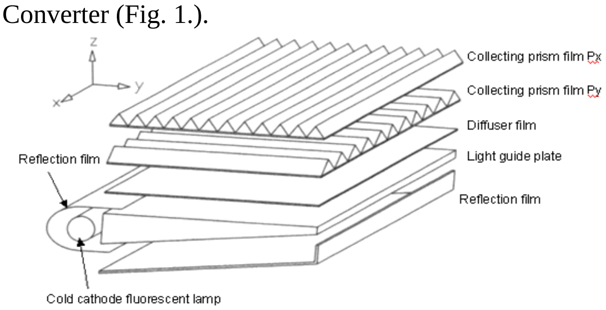

Fig. 1. Backlight Module Structure

2.2 LED backlight module

At present, LEDs have not yet been widely applied to large-size bottom lighting. For some common smaller size edge lighting applications, the three colors of red, blue and green first undergo optical mixing in the light guide structure or in the optical mixing area, then enter the backlight module, and are applied to various kinds of edge lighting structures.

3. Optical design theorem

3.1 Snell's law

The angle between the incident light and the normal to the interface is called the incident angle I_1; after refraction, the angle between the emergent light and normal to the interface is called the emergent angle I_2. The product of the sine of each angle and the corresponding refractive index of each medium is a constant:

$$n_1 \sin I_1 = n_2 \sin I_2 \tag{1}$$

3.2 Total internal reflection

When the light crossing the interface moves from a denser medium into a lighter one, the refracted light will further deviate from the normal line. When the incident angle increases to a certain angle such that the refracted angle equals 90 degrees, that incident angle is referred to as the critical angle.

$$I_c = \sin^{-1} \frac{n'}{n} \tag{2}$$

4. Results and discussion

4.1 Non-prismatic glass light guide plate design

To achieve a thin backlight module and to reduce the cost by combining the functions of diffuser and prismatic glasses into the light guide plate and by decreasing the costly purchased components (for example, prismatic glasses) . By use of integrated design, a microstructure is combined with the light guide plate to replace two prismatic glasses.[1-2] The reflection configuration at the bottom of the light guide plate is dominated by the cut-off cone angle and by the design of its top pyramidal structure (convex or concave type) and long trench structure (Fig. 2.)[3-5].

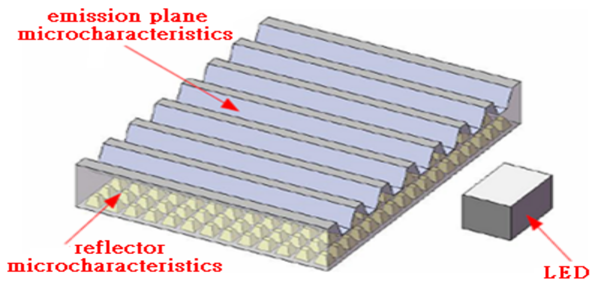

Fig. 2. Integrated Light Guide Plate

4.2 Taguchi method in combination with principal component analysis

The Taguchi method L9 may be combined with principal component analysis. All quality characteristic factors appear in linear combination. This analysis calculates the weight according to characteristic values of the principal component, computes the total points, and takes them as the standards for evaluating multiple quality characteristics.

4.3 The Incident-plane Characteristics Design of Light Guide Plate

The light guide plate is designed to be 3.5 inches, its thickness 0.76 mm, the bottom reflective film's thickness 0.125 mm, and the whole backlight module has 0.9 mm thickness. Light source uses 6 LEDs. Some changes in angles of the lamp shade have been made to increase the luminous flux. A torus lens is added to the light guide plate LED to let more rays arrive at the light guide plate bottom (as shown in Figure 10), and make the rays more even with the help of microstructure design at the bottom and top of the light guide plate.

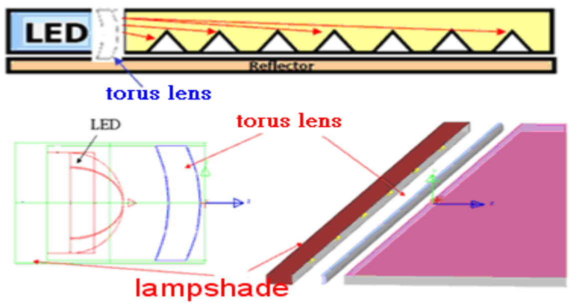

Fig. 3. LED Incident-plane Design.

4.4 Microstructure Size

In the microstructure design, the Taguchi method in combination with principal component analysis was utilized to obtain better illuminance uniformity and surface luminance, and obtain a better cut-off angle for vertebra microstructure sizes of Width = 0.05 mm, Length = 0.06 mm, Angle = 55 degree, and Height = 0.034 mm. Then this microstructure layout was applied to the light guide plate.

5. Conclusions

The Taguchi method in combination with principal component analysis led to an improved size of the microstructure, and determined the layout at the bottom of light guide plate. The lightTool simulation software optimized the microstructure density distribution at the bottom of the light guide plate so as to replace the prismatic glass and diffuser. With the present light guide plate, the average emission plane nine-point brightness was measured as 3090 nit (cd/m^2) and the brightness uniformity was 73 % as indicated in Table 1 (Fig. 4.).

Table 1. Nine-point Brightness Measurement

P1	P2	P3
2800	2929	3115
P4	P5	P6
2846	3378	3829
P7	P8	P9
2868	2955	3087

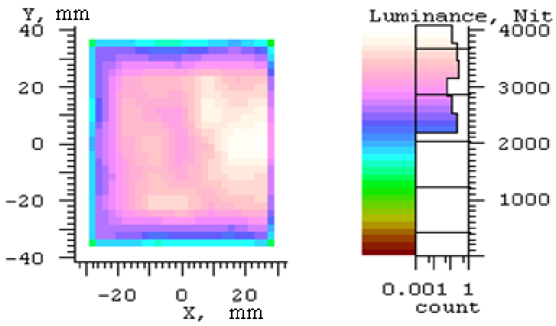

Fig. 4. Light Guide Plate Emission Plane Spatial Brightness

6. ACKNOWLEDGEMENT

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