

Light-Guide Plate with Curve-Ridged Micro Structures

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Abstract

In this paper, the scheme of a light-guide plate with the curved-ridge micro structures is proposed to reduce the usage of the brightness enhancement film (BEF) and maintain the luminous intensity at 0 degree angle. Due to the reduction of the BEF, the light efficiency can be increased and the cost can be reduced.

Author Keywords

light-guide plate; curve-ridged micro structure; backlight unit; liquid-crystal display.

1. Introduction

ESG is the abbreviation of Environmental Protection (Environment), Social Responsibility (Social) and Corporate Governance (Governance). As the demand for ESG products increases rapidly, how to reduce carbon emissions during the manufacturing process has become a main goal for many companies [1]. In this paper, the scheme of the light-guide plate with curve-ridged micro structures is proposed to reduce the usage of the brightness enhancement film (BEF) and maintain the luminous intensity at 0 degree angle. The optical characteristics of the proposed scheme are compared with those of the light-guide plate with laser-dot micro structures.

2. Optical Simulation

For the edge-lit backlight unit of the liquid-crystal display, the light guide plate is used to guide the strip light source incident from the side to the plane light source emitted along the normal direction of the light-guide plate [2]. The length, width, and height of the light-guide plate are denoted as L, W, and H, respectively as shown in Figure 1. The traditional design of the micro structures of the light-guide plate is the hemi-spherical dot which is produced by the laser beam. Additionally, two diffuser films and two brightness enhancement films (BEFs) are required above the light-guide plate to concentrate the light to the normal direction of the light-guide plate [3, 4]. The bottom and sides of the light-guide plate are combined with high-reflective films to increase light-guide efficiency.

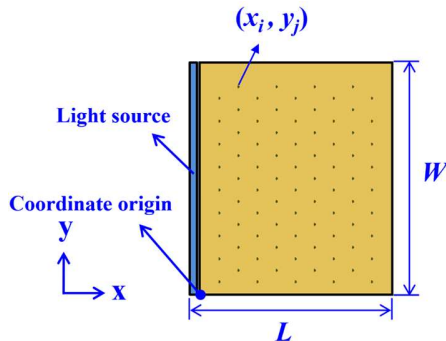


Figure 1 Schematic figure of the top view of the light-guide plate.

The coordinate position (x_i, y_j) of the hemi-spherical dots are

defined as:

$$x_i = i^\alpha \cdot \Delta x \quad (1)$$

$$y_j = (j - 1/2) \cdot \Delta y \text{ (for } i = 1, 3, 5, 7, 9 \dots) \\ = j \cdot \Delta y \text{ (for } i = 2, 4, 6, 8, 10 \dots) \quad (2)$$

where i and j denote the numbers of the hemi-spherical dot along the x-axis and the y-axis, α denotes the exponential coefficient along the x-axis, Δx and Δy denote the periods of the hemi-spherical dot along the x-axis and y-axis, respectively. For the illustration, the size of the light-guide plate is designed to be 14.2 inches with a length L of 194 mm, a width W of 303 mm, and a height H of 0.5 mm, respectively. There are 60 mini LEDs for the strip light source with a size of the light-emitting area of each mini LED of 2.80mm×0.46mm. The distance between adjacent mini LEDs is 5 mm and the luminous flux of each mini LED is 9 lm. The 60 mini LEDs are closely attached to the center of the side of the light guide plate. The hemi-spherical dot is designed as concave profile as to the light-guide plate with a curvature radius of 10 μ m and a height of 4 μ m as shown in Figure 2.

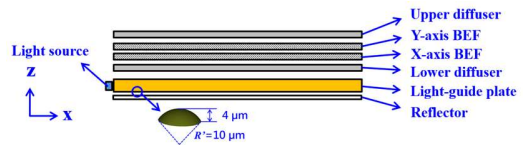


Figure 2 Schematic figure of the side view of the light-guide plate with laser-dot micro structures.

After the optimization analysis, the value of the exponential coefficient α along the x-axis is 0.7. The values of the periods Δx and Δy of the hemi-spherical dot along the x-axis and y-axis are 360 μ m and 360 μ m, respectively. The total number $i \times j$ of the hemi-spherical dots is 7982×841. The simulation results of the luminous intensity along x-axis and y-axis is shown in Figure 3 by using the optical software (ASAP, Breault Inc.). The simulation results of the luminous intensity before and after the light passing through the x-axis and y-axis BEFs are also compared. The simulation results show that after the light passes through the x-axis and y-axis BEFs, the luminous intensity I at 0 degree angle increases from 56 cd to 174 cd. The light efficiencies before and after the light passing through the x-axis and y-axis BEFs are 48.5% and 23.9%, respectively. Since the human eye's response to luminance is a logarithmic function, the logarithmic curve of the illuminance $\log(E)$ along the x-axis of the light detector above the BEFs is shown in Figure 4. The uniformity of the illuminance is defined as $\log(E_{\min})/\log(E_{\max})$. According to the positions of 9-points-luminance-measurement of the light-guide plate, the uniformity is calculated to be 90.8%.

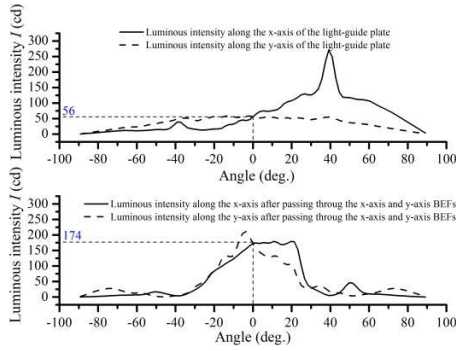


Figure 3 Luminous intensities of the light-guide plate with laser-dot micro structures before and after passing through x-axis and y-axis BEFs.

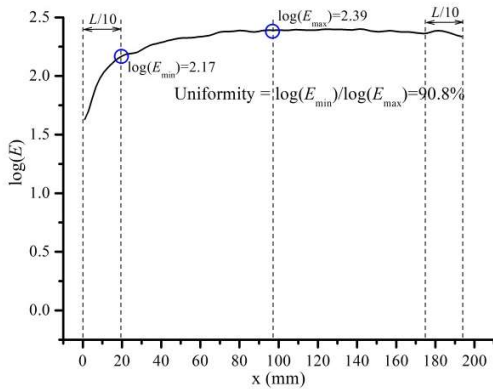


Figure 4 Logarithm values of the illuminance of the detector above the light-guide plate with laser-dot micro structures.

The light-guide plate with curved-ridged micro structures is proposed as shown in Figure 5. The cross-sectional profile of the curved-ridged micro structure in the x-z plane is an isosceles triangle with a vertex angle of 80 degree and a height of $6 \mu\text{m}$. The curved-ridged micro structure is formed by rotating the isosceles triangle along a rotation axis $10 \mu\text{m}$ away from the vertex of the isosceles triangle in a direction away from the strip light source. The angle of rotation along the rotation axis is ± 30 degree. The simulation parameters are the same as those of traditional light-guide plate. The simulation results as shown in Figure 6 show that after the light passes through only one y-axis BEF, the luminous intensity I at 0 degree angle increases from 175 cd to 177 cd, which maintains the luminous intensity at 0 degree angle compared to that of the traditional light-guide plate. The light efficiencies before and after the light passing through only one y-axis BEF are 57.0% and 38.9%, respectively as shown in Figure 7. According to the positions of 9-points-luminance-measurement of the light-guide plate, the uniformity is calculated to be 93.2%.

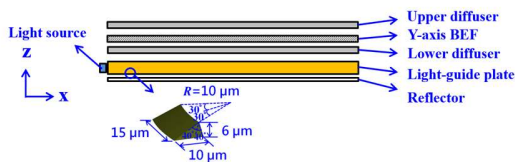


Figure 5 Schematic figure of the side view of the

proposed light-guide plate with curved-ridged micro structures.

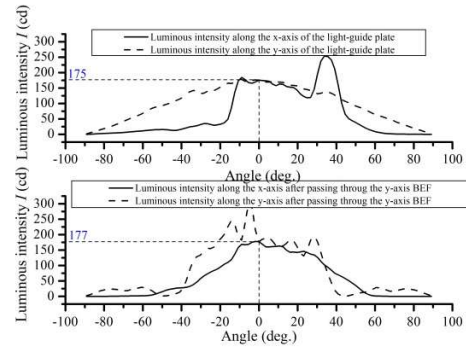


Figure 6 Luminous intensities of the proposed light-guide plate with curve-ridged micro structures before and after passing through y-axis BEF.

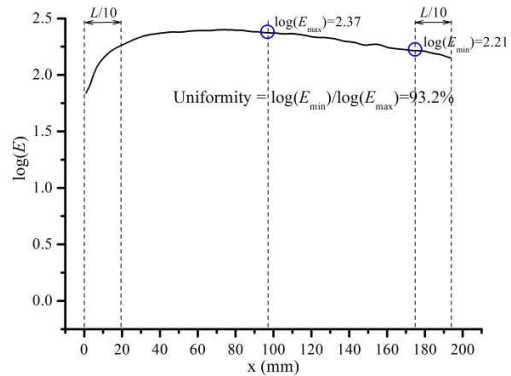


Figure 7 Logarithm values of the illuminance of the detector above the light-guide plate with curve-ridged micro structures.

3. Fabrication Tolerance

The photolithography process is chosen for the fabrication of the proposed curved-ridged micro structures on the photoresist material. Then the proposed light-guide plate is then fabrication by using the electroforming and injection processes. The fabrication errors will cause deviation of the profile of the micro structure. Therefore, the impact of the deviation of the profile of the curved ridge micro structure on the optical characteristics needs to be further analyzed. Due to the fabrication error, the cross-sectional profile of the curved-ridged micro structure in the x-z plane becomes an isosceles triangle with a vertex angle of 60 degree and a height of $6 \mu\text{m}$. The luminous intensity of the proposed light-guide plate with the 60-degree vertex-angle curve-ridged micro structures is shown in Figure 8. The angle of the peak of the luminous intensity along the x-axis is shifted to around -30 degree.

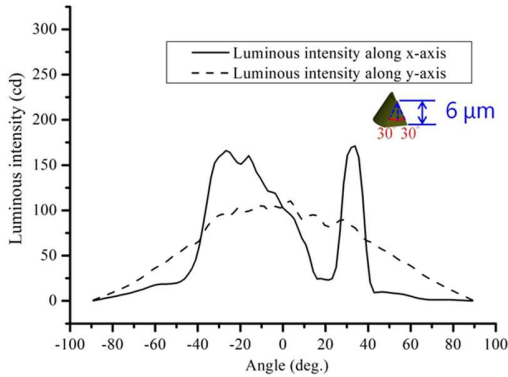


Figure 8 Luminous intensities of the proposed light-guide plate with the 60-degree vertex-angle curve-ridged micro structures.

Due to the fabrication error, the cross-sectional profile of the curved-ridged micro structure in the x-z plane becomes an isosceles triangle with a vertex angle of the 100 degree and a height of 6 μm. The luminous intensity of the proposed light-guide plate with the 100-degree vertex-angle curve-ridged micro structures is shown in Figure 9. The angle of the peak of the luminous intensity along the x-axis is shifted to around 5 degree.

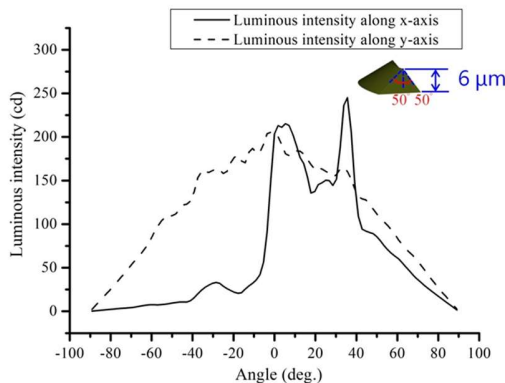


Figure 9 Luminous intensities of the proposed light-guide plate with the 100-degree vertex-angle curve-ridged micro structures.

Due to the fabrication error, the rotation angle the rotation axis becomes ±15 degree. The luminous intensity of the proposed light-guide plate with the 30-degree rotation-angle curve-ridged micro structures is shown in Figure 10. The width of the luminous intensity along the x-axis becomes wider.

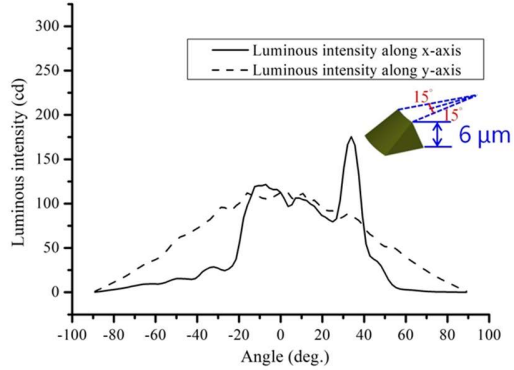


Figure 10 Luminous intensities of the proposed light-guide plate with the 30-degree rotation-angle curve-ridged micro structures.

Due to the fabrication error, the rotation angle the rotation axis becomes ±45 degree. The luminous intensity of the proposed light-guide plate with the 90-degree rotation-angle curve-ridged micro structures is shown in Figure 11. The width of the luminous intensity along the x-axis becomes narrower.

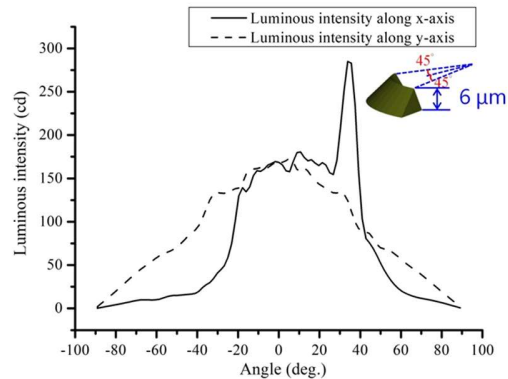


Figure 11 Luminous intensities of the proposed light-guide plate with the 90-degree rotation-angle curve-ridged micro structures.

Simulation results show that the fabrication tolerance of the vertex angle of the isosceles triangle of the cross-sectional profile of the curved-ridge micro structure is within 80 ± 20 degree. Simulation results also show that the fabrication tolerance of the rotation angle along the rotation axis 10 μm away from the vertex of the isosceles triangle in a direction away from the strip light source is within 60 ± 30 degree.

4. Fabrication

The curved-ridged micro structures of the proposed light-guide plate as shown in Figure 12 and Figure 13 is fabricated by using the maskless digital lithography technology (DLT) with an overlay accuracy of 1 μm. The 3D profiles of the curved-ridged micro structures are measured by the confocal microscopy (Keyence Inc.) and the cross-sectional profile of the curved-ridged micro structures is shown in Figure 14. The vertex angle of the isosceles triangle of the cross-sectional profile of the curved-ridge micro structure is about 81.698 degree ($= 180 - 48.575 - 49.727$) which is within the fabrication tolerance. After the curved ridge microstructure is fabricated by the laser direct writing exposure equipment, the

light guide plate will be fabricated by using the electroforming and injection processes.

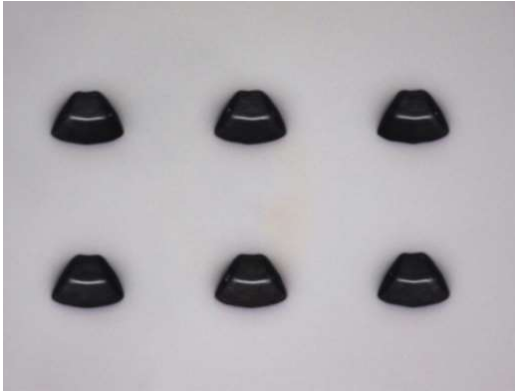


Figure 12 Top view of the curved-ridged micro structures

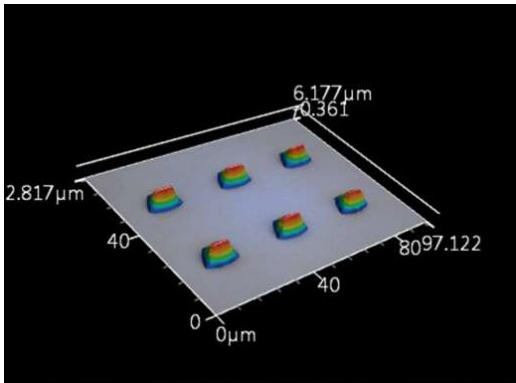


Figure 13 3D profiles of the curved-ridged micro structures.

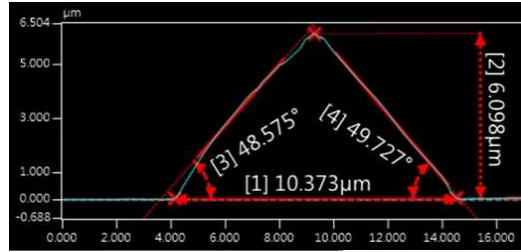


Figure 14 Measurement results of the cross-sectional profile of the curved-ridged micro structures.

5. Conclusion

In this paper, the scheme of the light-guide plate with curve-ridged micro structures is proposed to reduce one brightness enhancement film (BEF) and increase the light efficiency with the same luminous intensity at 0 degree angle. The curved-ridged micro structures of the proposed light-guide plate is fabricated by using the maskless digital lithography technology (DLT). The light efficiency can be increased and the cost can be reduced due to the reduction of the usage of one BEF.

6. References

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