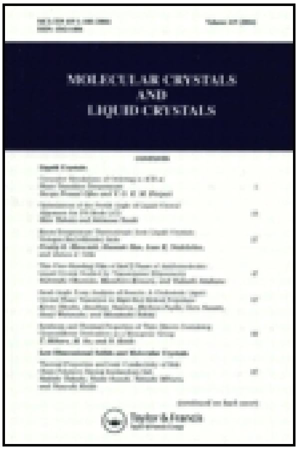

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LCD Backlighting Systems with a High Luminance and a Good Uniformity

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LCD Backlighting Systems with a High Luminance and a Good Uniformity

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We performed a 3-dimensional Monte Carlo simulation based on the Mie light scattering theory to investigate the photometric properties of a scattering polymer type light guide, that is known to give a very good brightness. The results reveal that the uniformity of the light guide with polymer scatterers abruptly decreases as the length of the light guide becomes larger than 20 cm. To improve the uniformity of the light guide, we employed a wedge-shaped light guide with dot patterns along with polymer scatterers. As a result, we were able to obtain a backlighting system satisfying a good uniformity and a high luminance at the same time.

Keywords: backlighting system; scattering polymer; dot pattern; Mie scattering; Monte Carlo method

INTRODUCTION

Liquid crystal displays (LCDs) targeting personal multimedia displays preferably need to match or exceed cathode ray tube (CRTs) performance in terms of image quality. Especially, for wide applications to outdoor use, LCDs must be bright enough to be sunlight readable. Since LCDs are non-emissive displays, they usually employ backlighting systems. However, a conventional polymethyl methacrylate (PMMA) type backlighting system reveals much transmission loss due to the structural problem of a light guide with diffusive dots printed on its bottom surface, thereby leading to insufficient brightness.

Recently, to improve the efficiency of the light guide a highly scattering optical transmission polymer has been proposed.[1,2] The light guide with the scattering polymer employs neither diffusive dots nor other geometrical patterns, but contains a specified microscopic heterogeneous structure to control the light transmission properties. Simply due to multiple light scattering within the highly scattering optical transmission polymer, the backlighting system with the polymer is reported to show high brightness and good uniformity. From our simulation results, however, it is revealed that for a large size display panel the luminance abruptly decreases on the opposite side of the lamp and thus the uniformity of the luminance cannot be obtained.

In this paper, we report on a light guide scheme employing both a highly scattering optical transmission polymer and diffusive dot patterns on the bottom surface of the light guide, to improve the brightness and uniformity of the backlighting system simultaneously. For this structure, we optimized the polymer material and the dot patterns by performing 3-dimensional Monte Carlo simulation based on the Mie scattering theory.[3,4] Under optimized conditions, the luminance of this system has been found to be very high and uniform.

RAY TRACING PROCEDURE

In the light guide with polymer scatterers, the photons radiating from the lamp travel through the scattering polymers repeating both scattering and reflection, and finally emerge from the top surface of the light guide. The scattering phenomenon can be exactly described by the Mie scattering theory. The scattering angle, defined by the probability distribution function, can be expressed by the following equation[1]:

$$F(\theta) = \frac{I(\theta)\,\omega(\theta)}{\int_0^{\pi} I(\theta)\,\omega(\theta)\,d\theta} \approx random \;\; number \qquad (1)$$

where $I(\theta)$ is a scattering intensity given by the Mie theory and $\omega(\theta)$ is a solid angle. The random number can be obtained from a random number generator. The photon path length is determined by the size and concentration of a scattering particle and by scattering efficiency given by[1]:

$$L = \frac{-\ln(random\ number)}{\pi r^2 K C} \tag{2}$$

where r stands for the radius of a scatterer, K for the scattering efficiency, C for the concentration of the polymer scatterer.

The structure of the light guide used in the calculation is schematically shown Figure 1. The reflection indices of the PMMA and the polymer particle are 1.49 and 1.43, respectively. The wavelength used here is 630nm. For the boundary conditions, at the top surface of the light guide, refractions and total reflections are considered, whereas at the bottom surface ideal reflections and diffused reflections are considered to represent both the reflector and the dot patterns. Here, the photons are repeatedly scattered by the polymer particles and randomly reflected by the dot-patterns printed on the bottom surface of the light guide.

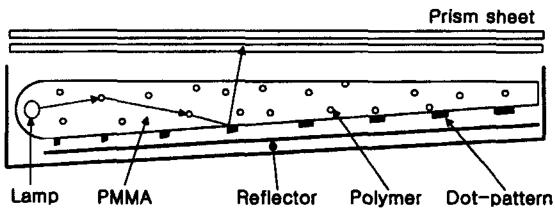


FIGURE 1. Illustration of the wedge-shaped light guide with printed dot-patterns and polymer scatterers.

RESULTS AND DISCUSSION

Figure 2 shows the scattering angle dependence of the scattering intensity for polymer scatterers of varying radius. Figure 2 shows that the scattering angle decreases as the size of the scatterers increase. This result implies that the size of scatterers exerts a significant effect on the scattering angle.

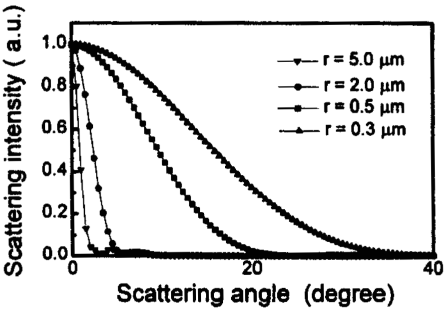


FIGURE 2. Dependence of the scattering intensity on the scattering angle for various scatterers of radii ranging from 0.3 ~ 5.0 μm .

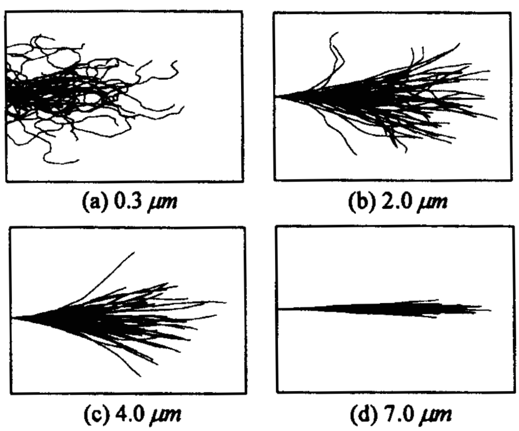


FIGURE 3. Scattering behavior of 100 photons injected on the center of the left side into polymer particles of (a) 0.3 μm (b) 2.0 μm (c) 4.0 μm (d) 7.0 μm in radius.

Figure 3 shows multiply scattering traces of photons injected on the center of the left side into three different kinds of scatterers having different radius. For polymer scatterers of about 0.3 μm , the scattering is concentrated in the vicinity of the point into which the photons are injected, thereby preventing the photons from reaching the opposite side of the lamp. For polymer scatterers of radius more than 5 μm, most photons undergo only refractions. These results collectively suggest that polymer particles of 2 ~ 4 μm in radii are effective scatterers.

Figure 4 shows the path of the photons travelling across the light guide. A photon starts out from an arbitrary point, which is determined by a random number generated from a random function, and travels with repeated scatterings and reflections until it comes out of the top surface of the light guide. At the top and bottom surfaces of the light guide, photons undergo refraction or total reflection according to the boundary conditions. In the calculation, the concentration and the radius of the polymer scatterers are 0.2 wt% and 3 μm, respectively.

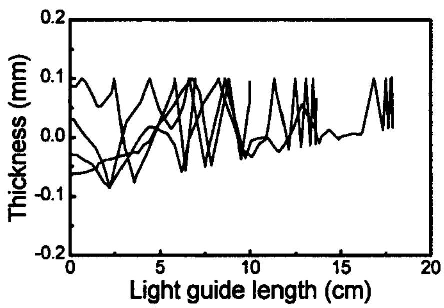
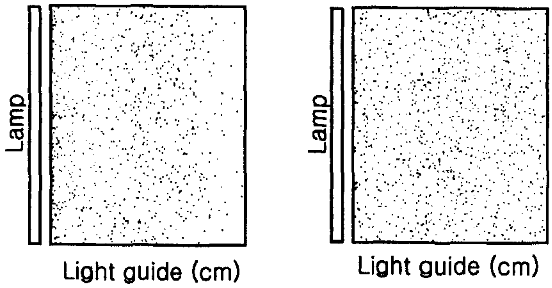


FIGURE 4. Ray tracing of light traveling within a light guide. 4 photons are randomly injected into the light guide

Figure 5 shows the output points of the photons as observed from the top surface of the light guide. In (a), the luminance of the light guide is seen uniform up to a certain range but abruptly decreases after that, whereas in (b), the luminance becomes not only uniform over the entire range but also considerably higher. One can deduce from these results that the LCDs of more than 10 inch in diagonal require the use of printed dot patterns along with polymer scatterers to achieve uniform luminance.



(a) Conventional scattering polymer type light guide.

(b) Wedge-shaped light guide with dot-patterns and polymer scatterers

FIGURE 5. Uniformity of the luminance observed from the top surface of the light guide

CONCLUSION

In order to improve the luminance uniformity of the scattering polymer type light guides for the large size liquid crystal displays of more than 10 inch in diagonal, we employed a wedge-shaped light guide with printed dot patterns in conjunction with polymer scatterers. For this structure, we performed a 3-dimensional Monte Carlo simulation using the Mie light scattering theory. Optimized conditions suggest that polymer particles of 2 ~ 4 μm radius are the most effective scatterers. When we varied the size of dot patterns to be in the range of 0.3 ~ 0.75mm, we were able to obtain backlighting systems with a good uniformity as well as a high luminance.

References

[1] Akihiro Horibe, Masahiro Baba, Eisuke Nih-ei, Yasuhiro Koike, *IEICE TRANS. ELECTRON*, Vol. **E81-C**, No. 11, pp. 1697-1702, (1998).
[2] A. Horibe, M. Baba, E. Nihei, Y. Koike, SID DIGEST, pp. 153-156, (1998).
[3] Wyn Brown, *Light scattering principles and development*, Oxford Science Publications, pp. 52-53, (1996).
[4] P.W. Barber, S.C. Hill, *Light Scattering by Particles : Computational Methods*, World Scientific, pp. 187-245, (1990).