Modeling and Design of Surface Roughness on the Top Surface of the Parallel Light Guide Plate of 3.5-inch Backlight Units for Brightness Uniformity

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ABSTRACT

At present, small-scale electronic products sold mainly employ edge-lighting backlight units. In this research, we first measure and analyze roughness parameters of the top surface of a 14-inch wedged light guide plate on which surface texturing is applied to obtain good brightness uniformity. Refer to these parameters, we model and design surface roughness on the top surface of a parallel light guide plate of a 3.5-inch edge-lighting backlight unit for brightness uniformity.

INTRODUCTION

For most medium- and small-size liquid crystal displays, edge-lighting backlight modules are used. To have uniform brightness for the backlight units, surface texturing on the top surface of a light guide plate (LGP) has been applied in the industry. For example, Mitsubishi Rayon [1] has proposed to add random textures on the top surface of a parallel LGP, For the top surface, the average slant angle is 0.3° to 30°. The ten-point average roughness is 0.7μm to 10 μm.

In this research, we use the professional optical simulation software, ASAP from Breault Research Organization, to simulate backlight units. We first measure and analyze roughness parameters of the top surface of a 14-inch wedged LGP on which surface texturing is applied to obtain good brightness uniformity. Refer to these parameters, we model and design surface roughness on the top surface of a parallel LGP of a 3.5-inch edge-lighting backlight module for brightness uniformity. For the LGP, it is made of PMMA and its bottom surface has periodic v-groove structure, which is perpendicular to the lamp. Figure 1 shows part of the cross section of the considered system, in which absorption surface is a virtual surface for simulation use only. Through appropriate design of the roughness parameters, we obtain exitance with good uniformity from the light guide plate.

MEASUREMENT

We measure and analyze roughness parameters of the top surface of a 14-inch wedged LGP on which surface texturing is applied to obtain good brightness uniformity. In previous research, we have confirmed this backlight unit has good brightness uniformity, mainly due to the surface texturing [2]. The surface texturing is formed by sandblasting first then followed by laser beam punching on the mold. Figure 2 shows one of the images of the top surface measured by the 3D laser microscope VK-8700 from KEYENCE. This laser microscope continuously scans the observation area at various depths and obtains the 3D profile of the sample. In Fig. 2, most of the area, which looks smooth, is formed by sandblasting, and there are some isolated pits formed by laser beam punching. We have made roughness measurement at 18 locations of the top surface of the LGP. After filtering of the high frequency noise and correction of the tilted substrate, the measurement results indicate that at sandblasted area and pits the rms slope varies from 0.03 to 0.09 radians and from 0.05 to 0.40 radians, respectively.

SIMULATION

We use ASAP from Breault Research Organization to simulate backlight units For the simulation of the randomly textured top surface of the LGP, instead of building its 3D profile in the ASAP, we employ a stochastic model for rough surface provided by the ASAP [3]. This model mainly uses rms roughness (*h*) and rms slope (*s*) to describe a rough surface. Two other minor parameters are autocorrelation length (*l*) and rms micro-roughness (*r*). Let's consider a PMMA/air rough interface and it is illuminated from PMMA with incident angle of 45°, as shown in Fig. 3. If the interface is absolutely smooth, the incident rays are totally reflected since the incident angle is greater than the critical angle, i.e., 42°. Now assume the rough interface has h=0.6 μm, s=0.2 radians, l=25 μm, and r=.10 nm. Figure 4 shows the intensity variation of reflected rays and transmitted rays. The transmittance is 13%. That means some of the incident rays overcome total internal reflection and transmit to the air. In general, the larger the slope, the higher the transmittance.

Based on roughness measurement results and the roughness model mentioned above, we design the surface texturing on the top surface of the LGP. We divide it into six long stripe areas, among them the first one is the smallest, as shown in Fig. 5. The rms slopes of these six areas are 0.0549, 0.1875, 0.2, 0.2514, 0.2514, 0.2514 radians, respectively. The rms values of roughness of these six areas are 53, 60, 50, 63, 87, and 116 nm, respectively. The effect of slope is much more significant than surface roughness. Therefore we adjust slope of each area to obtain uniform luminous exitance and high extraction efficiency from the top surface of the LGP. Extraction efficiency is defined as the ratio of the emitting flux of the top surface of the LGP to the emitting flux of the light source. The overall rms slope must be large enough, otherwise the extraction efficiency will be small. The rms slopes of the first three areas are made smaller than the next three areas to obtain uniform luminous exitance.

We assume five million rays are emitted from the lamp in the backlight unit in the simulation. Figure 6 shows good luminous exitance has been obtained. Better result can be expected by adjusting slopes further. Figure 7 shows intensity curves observed far above the LGP, and it indicates that most of emerging rays have angles of 30°~70° with respect to the normal. The extraction efficiency from the top surface of the LGP is 56%. This efficiency should be higher because about 10% of the emitting rays from the lamp stop at the top surface of the LGP and are not traced further by the ASAP due to unknown reasons.

CONCLUSIONS

We model and design surface roughness on the top surface of a parallel LGP of a 3.5-inch edge-lighting backlight unit for brightness uniformity. Good luminous exitance has been obtained. Better result can be expected by adjusting slopes further. The extraction efficiency from the top surface of the LGP is 56%.

Finally, we thank EFUN TECHNOLOGY and Mr. Qing Qin Wu very much for their great help in the measurement.

REFERENCES

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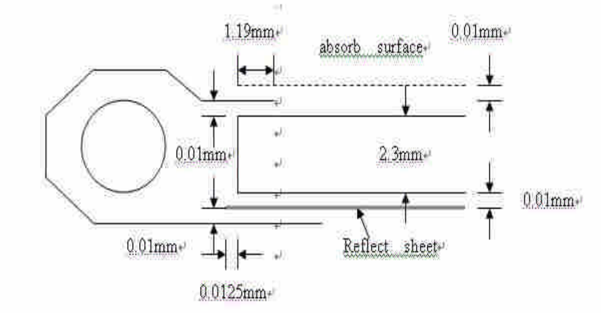

Fig.1. Part of the cross section of the considered 3.5-inch edge-lighting backlight unit.

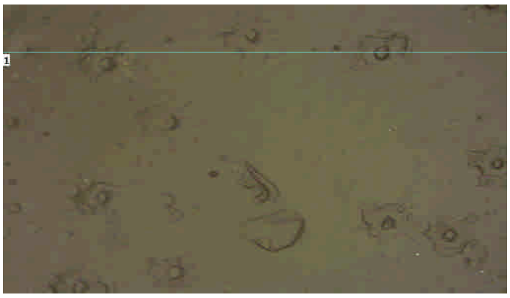

Fig. 2. One of the images of the top surface of the 14-inch wedged LGP measured by the 3D laser microscope VK-8700.

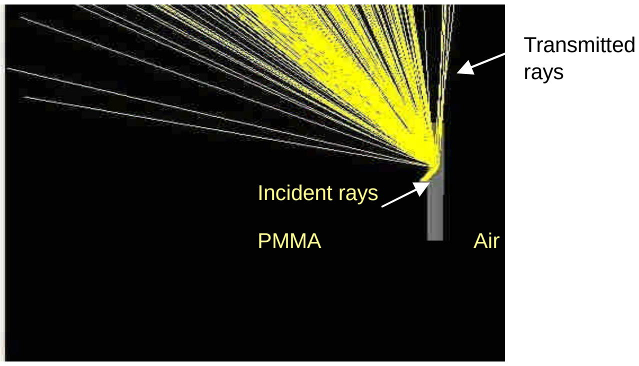

Fig. 3. A PMMA/air rough interface illuminated from PMMA with incident angle of 45°.

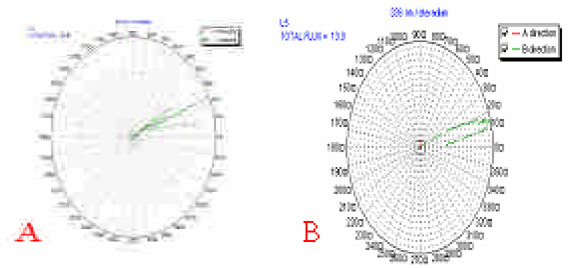

Fig. 4. The intensity variation of reflected rays and transmitted rays. A: for reflected rays; B: for transmitted rays.

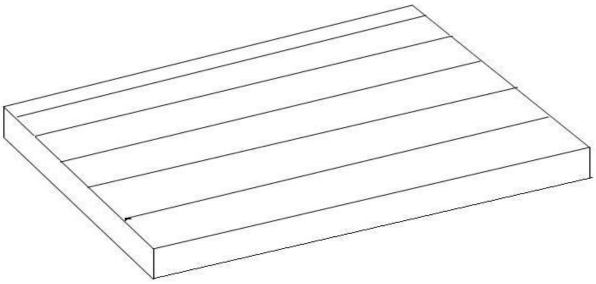

Fig.5. The top surface of the LGP is divided into six long stripe areas.

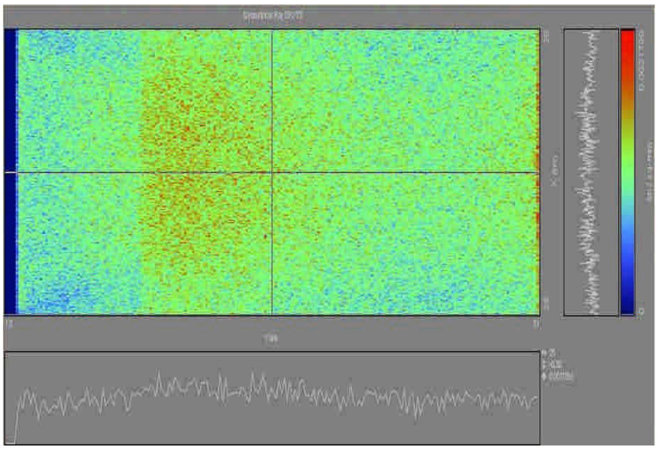

Fig. 6. Luminous exitance from the top surface of the LGP.

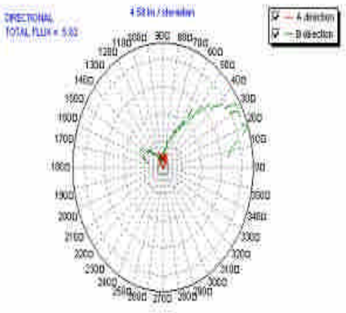

Fig.7. Luminous intensity curves observed far above the LGP.