Improving Light Extraction Efficiency of Monolithically Fabricated Micropatterned Light Guide Plate

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ABSTRACT

Light extraction efficiency is improved by Introducing new dumbbell-like extraction structures to the monolithically fabricated micropatterned light guide plate (LGP) in Ref. 1, 2. The fabricated 2.2 inch LGP with suggested structures shows an average luminance 4032 nit and 70 % uniformity with four side view 0.97 cd @15 mA LEDs. Without any additional optical film, > 20 % of luminance improvement is achieved compared to the one with ordinary circular extraction structures in Ref. 1, 2.

1. INTRODUCTION

Various ideas of making sheet-less backlight units (BLUs) are having been suggested to obtain a lower cost and thinner solution for LCD bussiness.

An LGP with monolithically fabricated micro -patterns on its surface [1, 2] can be one of the feasible approaches. However, the light extraction efficiency is propotional to the areal ratio, the opening area of extraction structures over the total area of LGP. In this paper, a new shape of extraction structure is suggested and fabricated to enlarge the areal ratio.

2. CONCEPT & DESIGN

The areal ratio of an ordinary circular structures [1,2] is 8.3%, when the opening 13um and the minimum spacing between structures 40um. It means that very small amount of available light budget can be extracted through the openings. The whole extraction efficiency of LGP is larger than this value because there are multiple encounters of the openings with back reflector, but still the available light remains inside the LGP.

We can make larger openings to obtain better areal ratio, but we can choose the horizontal direction only. If the opening has longer length of the longitudinal direction, the height of structure should become higher to ensure the whole light through the opening go upward.

Using bar-like structures as shown in Fig. 1(b) is the simplest way to obtain large areal ratio, but its angular distribution is not good as can be seen in the inset of Fig. 1(b). An additional film is needed for making it to the desired angular distribution.

As shown in Fig. 1(a), dumbbell-like structures can be a solution of this, the areal ratio is increased and also still has good angular distribution (no additional film needed). To verify this idea, we designed and fabricated a 2.2 inch LGP with dumbbell-like structures ontop. The longitudinal distances between structures were adjusted due to uniformity, and the distance of horizontal direction was fixed to 52 um. From the calculation of the designed LGP with LightTools, the luminance 5400 nit, the uniformity 78.2% were obtained.

3. FABRICATION

Figure 2 shows the fabrication process of suggested LGP. First, a 200 nm-thick Cr layer on a glass wafer was patterned using conventional lithography to make an embedded Cr mask (Fig.2 (a)). To fabricate a unit dumbbell-like bump, a pair of closely adjacent Cr circular patterns was required, and the distance between the two circles was carefully designed. In this experiment, the diameter of a circle and the distance between two close circles were 10 um and 13.2 um, respectively. After spin coating and soft bake of a 12 um-thick negative photoresist (AZ nLOF 2035 Clariant, Co., Ltd.) on the embedded mask, backside 3D diffuser lithography was conducted with the exposure dose of 10000mJ and the photoresist master was fabricated after development (Fig. 2 (b)-(c)) [1].

After the fabrication of the photoresist master, the dumbbell-like structures on the embedded mask were transferred via two times of PDMS replication; the first one was for an intermediate mold and the second was for the final LGP (Fig.2 (d)-(f)). In each replication step, self assembled monomer (SAM) was coated during the PDMS replication.

4. RESULTS

Figure 3 shows photographs of the fabricated unit dumbbell-like structure. Considering the valley at the center of the fabricated photoresist dumbbell –like bump (Fig. 3 (a)) and the dumbbell-like shape on the top of the intermediate mold Fig. 3 (b), the unit dumbbell-like bump was successfully fabricated as designed. The final PDMS LGP having the dumbbell-like structures was also successfully formed as shown in Fig. 3 (c).

The optical properties of the fabricated PDMS LGP were measured by a luminance colorimeter (EZContrast 160 from ELDIM S.A.) with four 0.97 cd @15mA LEDs at 3 points throughout the LGP (near, center, rear part of LGP from the light source). Fig. 4(a) and 4(b) show the measured luminance value at 0 and 90 degrees in each position respectively, with a mold frame of conventional one. The white mold frame has a reflectivity over 85%, and it improves the luminance and uniformity of the fabricated LGP by recycling light.

The average luminance was measured as 4032 nit with a uniformity of 70%, which showed the better performance compared to the previous one [1] (approximately 2878 nit with a uniformity of 73.3% with four 0.85 cd LEDs). The luminance improvement is 20% in the same source conditions.

5. SUMMARY

To improve the performance of a previously suggested monolithically fabricated micropatterned LGP, we suggested dumbbell-like micro structures, and verified the feasibility of concept by making of a 2.2 inch LGP with dumbbell-like structures shows its possible enhancement.

6. REFERENCES

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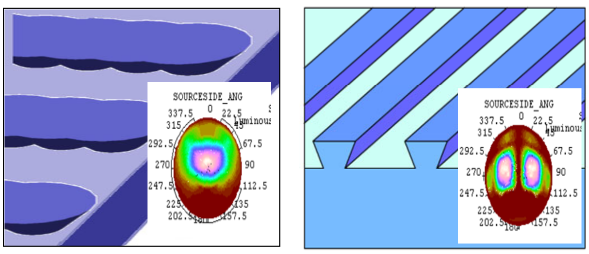
[2] J.-H. Lee, H.-S. Lee, B.-K. Lee, W.-S. Choi, H.-Y. Choi, and J.-B. Yoon, "Simple liquid crystal display backlight unit comprising only a single-sheet micropatterned polydimethylsiloxane (PDMS) light-guide plate," Opt. Lett. 32, pp. 2665-2667, (2007).



(a) (b)

Fig. 1 Shapes of light extraction structures, (a) dumbbell-like (b) bar-like.

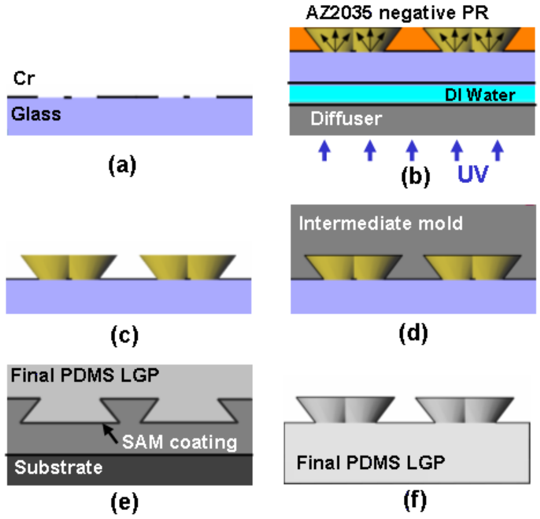
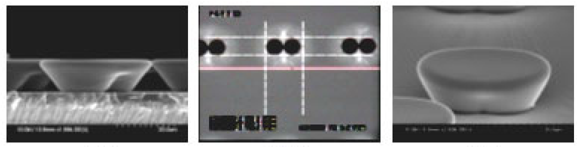
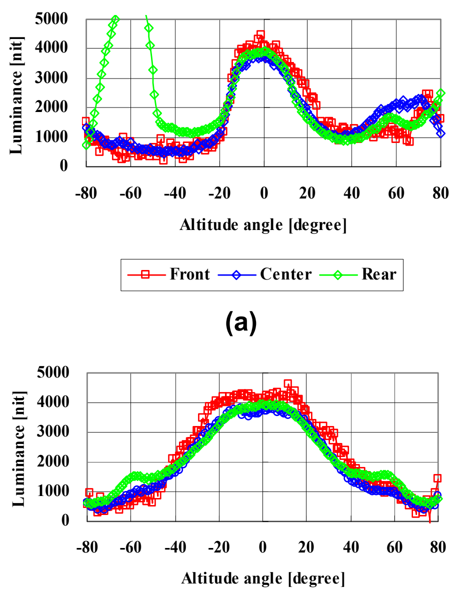


Fig. 2 Fabrication process of the dumbbell-like bump: (a) embedded mask, (b) backside 3D diffuser lithography, (c) photoresist mold after development, (d) replication of intermediate mold, (e) replication of final PDMS LGP, and (f) peeling off the final LGP from the intermediate mold.



(a) (b) (c)

Fig. 3 Images of the fabricated patterns: (a) SEM image of photoresist pattern, (b) top view image of intermediate mold using optical microscope, and (c) SEM image of the final PDMS LGP.



(b)

Fig. 4 Optical properties of fabricated LGP sample in the mold frame. The measured luminance value at (a) 0 degrees and (b) 90 degrees at 3 points of LGP (front, center, and rear position from the light sources).