The Application of Ansperical Microlens Array on Direct Backlight System

Chingfu Tsou*, Tenghsien Lai, Chenghan Huang, and Chunming Chang

Department of Automatic Control Engineering, Feng Chia University,Taichung, Taiwan, R.O.C.,
*cftsou@fcu.edu.tw

ABSTRACT

This paper reports the design of a novel aspheric microlens array (AMA) with high fill factor for direct light emitting diode (LED) backlight system. The AMA mold for patterning transformation was fabricated using the processes of glass wet etching, electroplating, photoresist spin coating and heating encapsulated air. Different from the fabrication results by well-known techniques, the proposed AMA has the features of 100% fill factor and square foot boundary with continuous surface-relief profile. A typical fabrication result, polysiloxine-based AMA with pitch size of 200 μm on a 4 inch glass wafer, has been used for the identification of the optical performance. Experimental results reveal that the radiation patterns and intensity profiles of the light source by using AMA as a light guide diffuser is highly effective in increasing the brightness and uniformity.

keywords－aspheric microlens array, fill factor, backlight system, diffuser

1. INTRODUCTION

Today's liquid crystal displays (LCDs) have to achieve more brightness and better uniformity in a thinner package, especially for the large-sized LCD panels with direct-type LED backlight system [1]. Different reflective and transmissive characteristics managed by several key elements are expected to significantly affect the brightness profile. However, commercial diffusing component consisting of lower diffuser, brightness enhancement film (BEF) and upper diffuser could reduce the brightness significantly with low uniformity. Thus, microlens array as a light diffuser became the most advanced solution [2, 3].

Microlens array typically provides a unique transition area that scatters the light uniformly. The size and shape of microlens as well as the configuration of microlens array may dominate the optical performance, such as the microlens array with high fill factor and continuous surface-relief profile can increase the light passing through and reduce the hot spots on the screen, and thus enhance the brightness and uniformity. But these properties are difficult to achieve with well-known techniques, such as thermal thermal reflow forming [4], stereolithography technique [5], mold insert [6] and hot intrusion process [7].

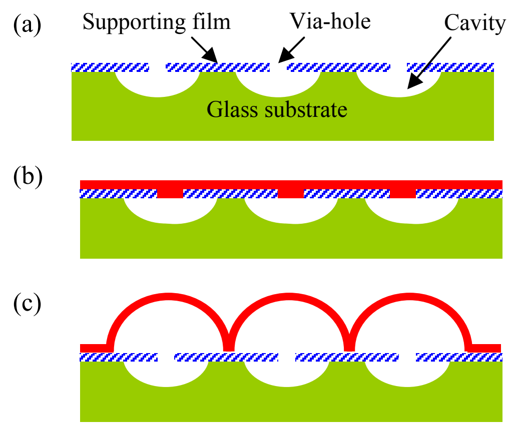

Figure 1. Schematic view of the design concept of AMA: (a) base structure, (b) photoresist coating and (c) semispherical-like shell forming by heating process.

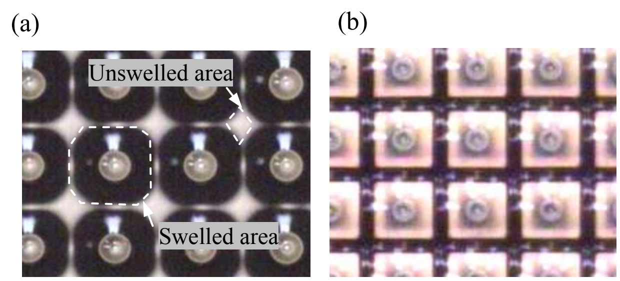

Figure 2. Optical images of the swelled photoresist with fill factors of (a) 80 and (b) 100%.

Based on the requirements for microlens applications, a microlens fabrication process with heating encapsulated air was developed in our previous works [8, 9]. This process is suitable for fabricating microlens array with high fill factorand continuous surface-relief profile. Consequently, this paper designs a novel AMA with fill factor of 100% for direct LED backlight system. Its optical performances in comparison with the commercial diffusing component were characterized, and confirmed that the AMA is effective in light extraction and a better uniformity of brightness can be achieved for direct LED backlight system.

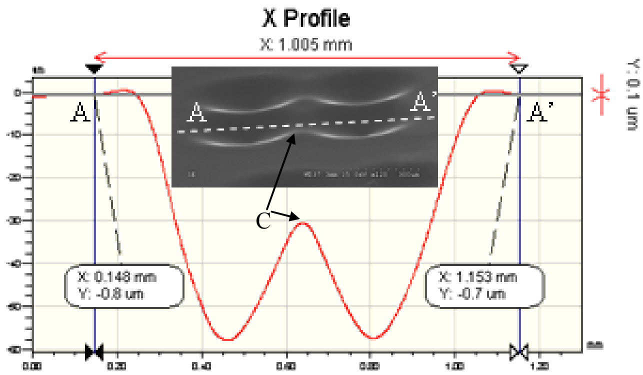

Figure 3. Surface profile of the 2×2 microlenses array.

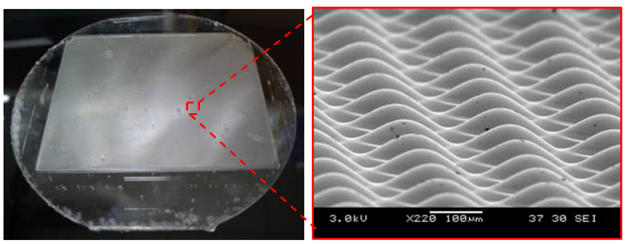

Figure 4. Images of the polysiloxine AMA with fill factor of 100%.

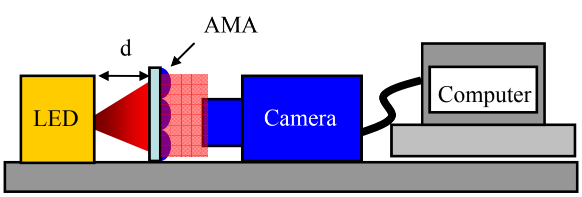

Figure 5. Measurement system for light source radiation

2. DESIGN AND FABRICATION

Figure 1 shows the schematic view of the design concept for forming the AMA mold. The glass substrate with cavity array served as the base structure, as shown in figure 1(a). The supporting film with via-hole patterning was used to determine the critical dimensions of glass etching window. Based on that structure, a viscous photoresist such as AZ4620 was spin-coated on the substrate to fill up the micro via-holes and to stay temporarily at the back-end window cavity. The structure shown in figure 1(b) is then heated by aheating apparatus. The photoresist on the micro via-holes could be swelled by the extrusion of volume expansion of the encapsulated air, as shown in figure 1(c), thereby causing the photoresist to reform into semispherical-like shells, and then solidified by cooling down as a convex microlens mold. Details of the fabrication process can be found elsewhere [9].

The typical fabrication results acquired from optical microscope are shown in figure 2. Figure 2(a) show that the fill factor of AMA is about 80% due to a portion of the area was unswelled. But an AMA with fill factor of 100% was fabricated by a higher heating process, as shown in figure 2(b). However, those figures show that the foot boundaries of microlenses are to be bound to each other and configure various continuous surface-relief profiles. Based on above photoresist mold, the nickel mold was fabricated by electroplating, and the surface profile of 2×2 microlens array was measured as well by interferometric profilometry, as shown in figure 3. The figure shows a continuous surface-relief profile was formed along the cross-section A-A', especially at the foot boundaries of neighbor microlenses that indicated by the symbol C. This unique feature is difficult to achieve with well-known techniques. In addition, the measured mean square surface roughness (R_a) is less than 3.5 nm, which is an excellent surface property for optical applications.

To characterize the optical properties of AMA for backlight system, the nickel mold was transformed to a polysiloxine-based optical element by mold pressuring. The fabrication result are shown in figure 4, which demonstrate a 100% fill factor of the 380×320 AMA with 200 μm pitch on a 4 inch glass wafer. Yield rate of the microlens is about 99%. The measured sag heights for all microlens are in the range of 45±1.6 μm. The light transmission (700 nm~1000 nm) and refractive index of the polysiloxine are 97% and 1.43, respectively.

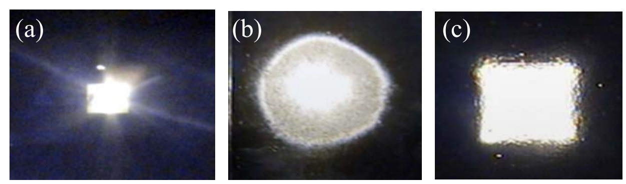

Figure 6. Radiation patterns of a single white LED: (a) pure light source and assembling AMA with fill factors of (b) 80 and (c) 100%.

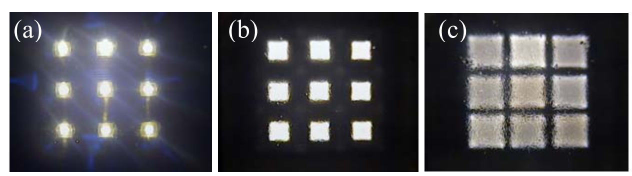

Figure 7. Radiation patterns of the 3×3 LED array with 1.5 cm pitch: (a) original light source, (b) with AMA; d=1 cm and (c) with AMA; d=2 cm.

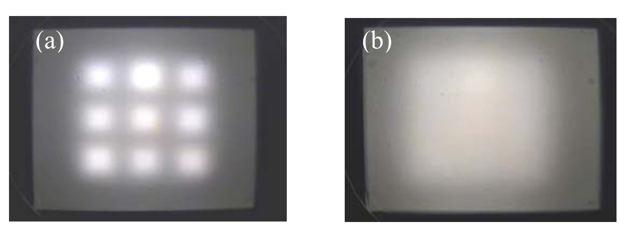

Figure 8. Radiation patterns of the 3×3 LED array with AMA and a commercial diffuser assembled for d is (a) 1 and (b) 2 cm, respectively.

NSTI-Nanotech 2009, www.nsti.org, ISBN 978-1-4398-1782-7 Vol. 1, 2009

3. MEASUREMENT AND DISCUSSION

The measurement system for radiation patterns of light source is shown in figure 5. The polysiloxine AMA element was placed in the front of LED with a distance *d*. The camera with computer connected was used to capture the radiation patterns of light source. The typical measurement results for a single LED and combining various fill factors of microlens array with the distance of 1cm are shown in figure 6(a)~(c). Figure 6(a) shows that the radiation pattern of light source is acquired from the original LED chip. Figure 6(b) shows that the case of AMA with fill factor of 80% resulted in a circular-like pattern. However, figure 6(c) shows that the AMA with fill factor of 100% has the feature for correcting the radial ray directly to a square pattern with uniform brightness. In the same way, the measured light patterns for 3×3 LED array with 1.5 cm pitch are shown in figure 7. According to the results in figure 7(b) and 7(c), the proposed AMA with high fill factor permits that a uniform large-sized backlight can be realized by synchronizing the point-array light source with square patterns.

(a)

(b)

(c)

(d)

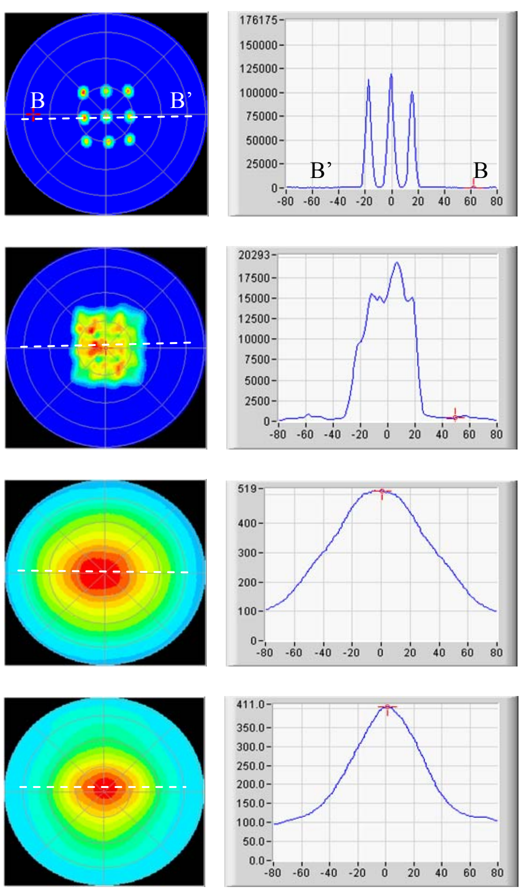

Figure 9. The measurement results of light intensity profile: (a) original light source of 3×3 LED array, (b) with AMA assembled, (c) with AMA and a peace of diffuser assembled, and (d) using commercial diffusing component. The units of X and Y Coordinates for all right figures are view angle in degree and Luminance in cd/m^2, respectively.

In addition, a better uniformity of backlight has been accomplished by combining the 100% fill factor of AMA with a commercial diffuser, as shown the measurement results in figure 8. The radiation patterns in figure 8(a) and 8(b) were captured by setting *d* equal to 1 and 2 cm, respectively. Those two images show that the figure 8b has a better uniformity in light radiation. Although an excellent brightness uniformity can be achieved by setting the distance *d* large than 2 cm, the thickness of backlight unit could be increased. However, the optimal size in package also needs to consider the pitch sizes of LED array and its arrangement.

The intensity profiles of light source and by assembling AMA without and with a diffuser attached, and commercial diffusing component (consisted of two diffusers and two BEFs) were measured by a Conoscope, as shown in figure 9(a)~(d), respectively. Figure 9(a) shows the luminance of pure light source with three peaks over 100000 cd/m^2. In figure 9(b), the peak values have dropped to 15000~20000 cd/m^2 due to the redistribution of light radiation through AMA. However, a better uniformity was obtained in comparison with that of figure 9(a). In addition, the cases of figure 9(c) and (d) show the brightness profile close to a parabolic. Their luminances to peak are about 510 and 410 cd/m^2, respectively. Those results revealed that the case with AMA can increase the light intensity by 20% and get better uniformity in comparison with that of commercial diffusing component. In summary, the novel AMA is effective in light extraction and uniform visual appearance can be achieved for direct LED backlight system.

4. CONCLUSION

A novel optical element, “AMA with fill factor of 100%”, has been applied into a highly efficient direct LED backlight. Experiment results have showed that the AMA can provide excellent performance in brightness uniformity due to its high fill factor with continuous surface-relief profile, and an increase in light intensity of 20% has been achieved in comparison with commercial diffusing component. The proposed diffusing component only required an AMA element and a peace of commercial diffuser. This simple diffusing unit without using BEF makes it very attractive for the customer to build and develop on their requirement.

ACKNOWLEDGMENT

This project was supported by the National Science Council of Taiwan under grant of NSC-96-2221-E-035-027-MY3 and Chi Mei Optoelectronics (CMO). The authors appreciate the Precision Instrument Support Center of Feng Chia University, and the NSC National Nano Device Laboratory (NDL) in providing the fabrication facilities.

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