A Novel Method to Fabricate Microlens Array with Normal Subwavelength Structures

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From the inspiration of moth-eyes[1], the compound structures could be applied to reduce the reflection of a nonplanar surface. Subwavelength structures (SWS) could be obtained over the surface of a microlens array by utilizing interference lithography directly[2]. However, the SWS not normal to the curved surface might increase the reflection at the curvy surface with large curvature. This paper demonstrates that by combining interference lithography, nanoimprint lithography and extrusive curve shaping[3] a microlens array with SWS normal to curved surface can be fabricated on a flexible substrate. And the experimental results show good antireflection performance on a single microlens.

In the experiment, the photoresist SWS were first patterned on a Si substrate by utilizing two-beam interference lithography. After the process of pattern transfer to Si by using DRIE, the Si mold with SWS was coated with an anti-adhesion layer on the surface by dipping it in a surface modified solution. Then the SWS on the Si mold were replicated to a flexible PC (polycarbonate) film by nanoimprint. Lastly, the PC film with SWS was extruded by a steel micro-hole array mold to form compound structures where the surface of microlenses was filled with SWS as shown in Fig. 1. The extrusion process oriented the SWS along the curved surface of microlens as shown in Fig. 2.

The reflectance at normal incidence was measured by our homemade varied-angle reflectometer. An objective lens was used to focus the incident beam spot to a single microlens. The microlens without SWS was measured first to serve as the baseline and then the microlens with SWS was measured. Among many microlenses with SWS, five were arbitrarily chosen for reflectance measurement, and all exhibited lower reflectance than those without SWS in the wavelength ranging from 400 to 700 nm. Fig. 3 shows that the reflectance ratio of a single microlens and the other 5 microlenses with SWS. An average ~30% decrease in reflectance was obtained over the spectral range. This method has the potential to improve light efficiency by applying the compound structures to the LED package and to the light guiding plates for LED backlight modules.

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References

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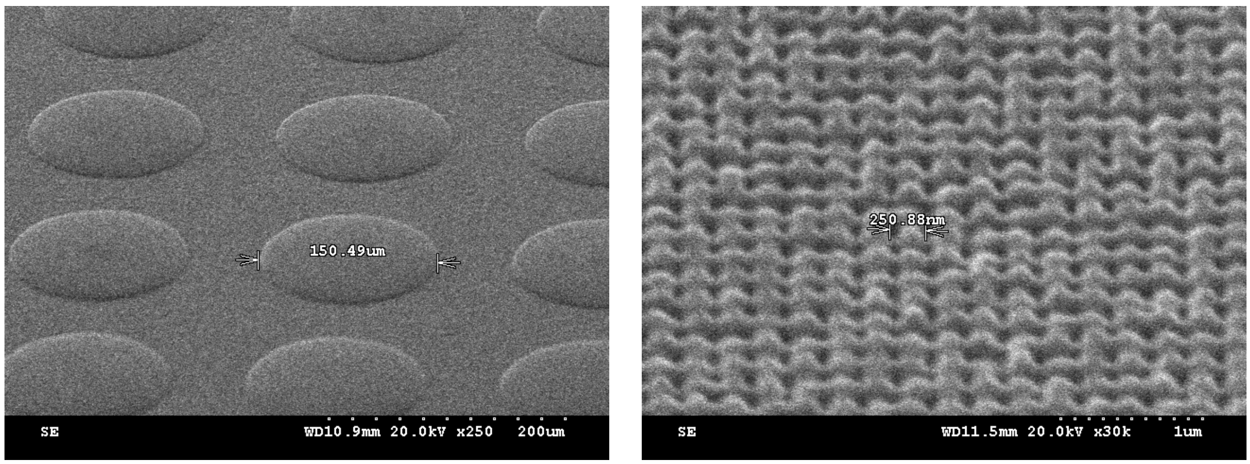

(a) (b)

Fig. 1 SEM images show the compound structures on a PC film; (a) the diameter of a microlens is 150 μm and (b) the period of the SWS is 250 nm.

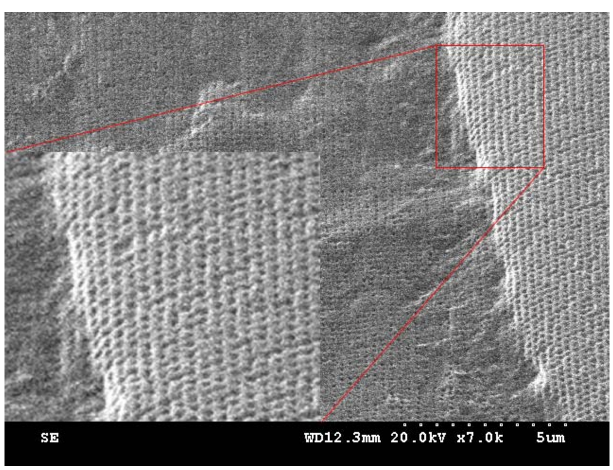

Fig. 2 SEM image shows the SWS would be oriented by the curved surface on the edge of a microlens which had a large curvature.

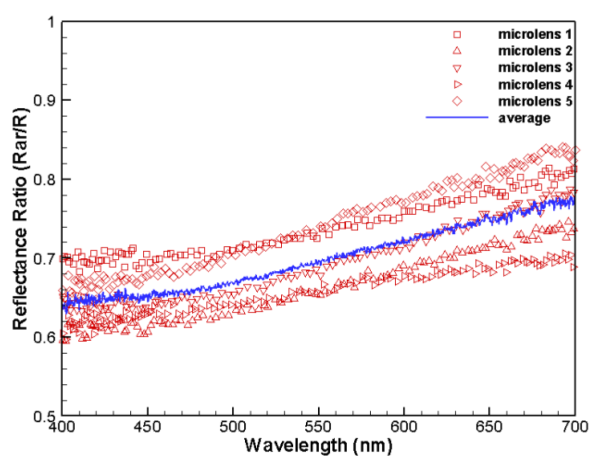

Fig. 3 The reflectance ratio of microlenses with SWS (Rar) to without SWS (R) in the wavelength ranging from 400 to 700 nm.