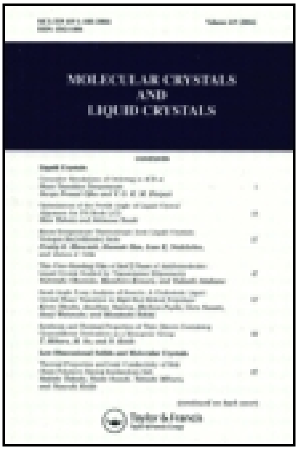

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Self-Developed Formation of Relief Optical Microlens by Dry Photopolymer

Hyun Jung Lee [a] & Kwan Sun Park [a]

[a] Samsung Advanced Institute of Technology, P.O.B 111, Suwon, Korea

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Self-Developed Formation of Relief Optical Microlens by Dry Photopolymer

HYUN JUNG LEE and KWAN SUN PARK

Samsung Advanced Institute of Technology, P.O.B 111 Suwon, Korea

Relief optical microlenses were prepared by using a self-developing method with photopolymers. The formation of the microlenses depended on the mass-transfer of photopolymer by diffusion and the difference of surface-free energy induced light source. The shape and height of lenticular lenses changed with the intensity of light, the exposed time and the temperature during the photopolymerization.

Keywords: photopolymer; microlens; relief structure

INTRODUCTION

Photopolymers have been extensively used in the fields of coating technology, optical and electronic industry[1]. They are important in holography technology for no requirement of wet chemical step, and the formation of an optical element by simple ultraviolet (UV) exposure. Recently, these materials are widely studied in data storage and processing[2]. Dry photopolymer forms a relief hologram by self-developing that is a process to record automatically by exposure of light. Dry photopolymerizable layers can be lead to improved characteristics for refractive-index imaging and to a microrelief embossing technology[3]. In addition, these material films were reported to be a suitable system for the fabrication of relief diffraction elements[4]. Therefore, it can be used in the field of optical elements like microlenses as well as the recording and storage of hologram.

In this study, the fabrication of microlenses is attempted by using dry photopolymer technique. The effects of the UV intensity, temperature and an exposure time controlling the characteristics of the generated relief are investigated. And the mechanism of relief formation is discussed.

EXPERIMENTAL

The mixture of acrylic monomers was used for the photopolymer. The mixture was consisted of a multifuntional, a diacrylic monomer and a photoinitiator, Irgacure 651 (Ciba-Geigy Co.) in this study. The results reported in this study were obtained with the same composition of the mixture.

The photopolymer was coated on the slide glass by a doctor knife. The thickness of the coated film was 100 ± 5 μ m. A stripe type photomask was used for the formation of lenticular lens. The polymerization was initiated by UV source (ORIEL) equipped 1000 W metal halide lamp (maximum absorption 365nm). The microlens fabrication process involved following steps: 1st illumination, which exposes through a stripe type mask for the relief formation; 2nd illumination, which exposes overall without the mask for fixing polymerization.

The effects of the temperature during crosslinking polymerization were studied by using thermo plate TP-80 purchased from Iuchi Co. (Japan). Surface Analyzer TN 2000 (MYKO, USA) analyzed the shape and height of fabricated lenticular lenses.

RESULTS & DISCUSSION

Figure 1 shows the experimental set-up and the formed lenticular lenes by photopolymer. The relief was produced not by shrinkage but by monomer mass transport. When the photopolymer is illuminated by UV light, the polymerization reaction is started by the initiation of the photosensitive initiator. The polymerization proceeds more rapidly at the illuminated surface of the film. As a result, a local change in monomer concentration appears and the internal strain resulting from the gradient of chemical composition relaxes through a mass diffusion process. This mass transfer induces the appearance of a local change in surface energy. A surface free-energy gradient causes the bending of the surface.

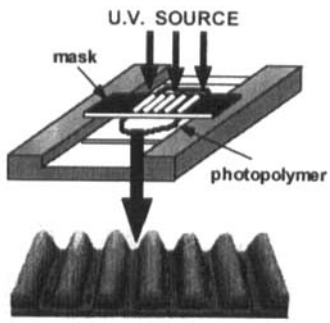

FIGURE 1. Scheme of the experimental set-up and fabricated lenticular lenses.

Figure 2 shows the shape and height of fabricated lenticular lenses by different exposing methods. The shape of lenticular lens in curve (a) showed concave. On the contrary, the shape of lenticular lens in curve (b) showed convex. The appearance of concave lens in curve (a) can be explained as a consequence of the diffusion of material and the internal strain by illumination. At the beginning of the exposure, monomers are converted into polymer at the illuminated regions, and lead to the transferring of reactive species towards the center of the bright area that forms a relief. In the case of the velocity of monomer diffusion from dark areas to bright areas is slower than that of polymerization at bright areas, the shape of lenticular lens will be a concave. In the case of curve (b) with the 10 minutes interval between 1st and 2nd illumination, the relief is heightened compared with relief (a) and forms the convex regardless the change of exposure time. This result means that the polymerization continued to develop after the end of the irradiation.

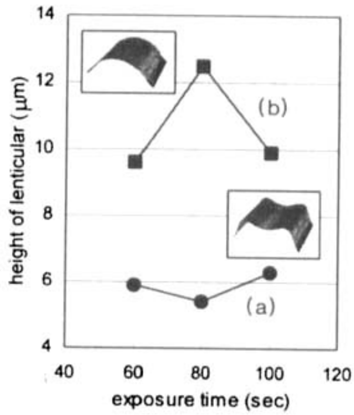

FIGURE 2. Shapes and heights of fabricated lenticular lenses by different exposing methods: (a) without interval between 1st and 2nd illumination (●), (b) with interval of 10 min (■).

Figure 3 illustrates the effect of UV intensity on the lenticular lens fabrication. All of the lenticular lenses showed convex shape. The height of lenticular increased with light intensity below 40 mW/cm^2 and the lenticular lenses showed almost same height above 40 mW/cm^2. This result means that the height of lenticular lens increases with UV intensity at the low intensity, but the height of lens is limited by the velocity of monomer diffusion at the strong UV intensity.

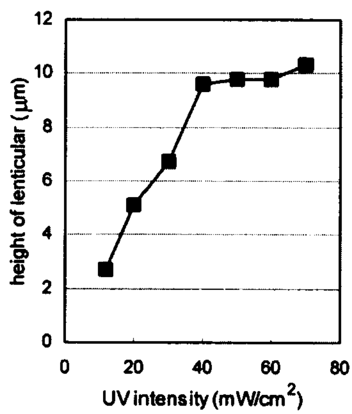

FIGURE 3. Height of lenticular lens fabricated at different intensity of 1st illumination (with 10 minutes interval between 1st and 2nd illumination)

Table 1 shows the temperature dependence of lenticular formation. When the temperature increases, the diffusion of monomer from the dark regions to the illuminated areas occurs easily. However, it is observed that the height of the

TABLE 1. Temperature dependence of lenticular lenses

Temperature (°C)		20	25	30	40	50	60
(a)[a]	Height (μm)	2.8	3.6	4.5	5.5	6.5	7.3
	Shape						
(b)[b]	Height (μm)	6.6	6.9	9.5	11.2	10.6	7.4
	shape						

[a]2nd illunination after 1st illumination. [b]10 minutes interval between 1st and 2nd illumination.

lenticular lens decreases above 40 °C in the case of curve (b). The reason is that the mobility of the monomer from illuminated areas towards dark area increases. It is also found that at the low temperature the relief is not developed and the phases of the photopolymer mixture are separated (Figure 4).

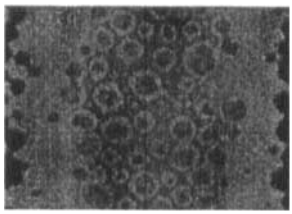

FIGURE 4. Microphotograph of the fabricated lenticular lens at 10 °C

CONCLUSION

Dry photopolymer was suitable system for the fabrication of microlens. The process of the relief formation was found to depend on the diffusion of monomer and a surface-free energy gradient. It was found that the polymerization process did not stop immediately after the end of the illumination but proceed as a post polymerization in the dark, causing the further development and enlargement of the relief. The shapes and height of the lenticular lenses changed with the exposed light intensity, the illumination time and the temperature at which the polymerization was occurred.

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