Large-area microlens arrays fabricated by integrated gas-assisted UV-curing Embossing with UV-LED array lamp

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Abstract

Recently, the microlens arrays have been used in many electro-optical applications. Replication of plastic microlens arrays from master of micro-holes array using injection molding and hot embossing have been widely used. However, injection molding is difficult to mold large and thin plates due to the huge flow resistance. Hot embossing is limited in large-area replication due to the difficulty in achieving uniform pressure distribution over large area using hot platens and in reducing the heating/cooling time. In this study, a gas-assisted UV-curing embossing process for effective fabrication of large-area microlens array at room temperature and with uniform pressure has been proposed. This process integrates the gas-assisted embossing and the UV-curing embossing processes. The gas-assisted embossing provides the uniform pressing pressure over the whole large area, while the UV-curing embossing enables the process to perform without heating and cooling and under low pressure.

Fig.1 shows the fabrication procedure of large-area microlens arrays. Since the traditional UV-lamp is linear light source and it is difficult to provide a uniform irradiation over large-area, an UV-LED array lamp (λ = 375-395 nm) as shown in Fig. 2 has been designed and implemented for uniform irradiating large-area. During the gas-assisted UV-cured embossing process, the PMMA substrate is pressed against the stainless-steel stamper coated with UV-curable resin. Under the gas pressuring and UV irradiating, a large array (over 1500 x 1500) of resin microlenses has been successfully fabricated onto a 203mm x 230mm PMMA substrate. Fig. 3 shows the surface profile of the fabricated microlens array under the processing conditions of 5 Kgf/cm^2 of pressing pressure, 60 seconds of pressing duration (including UV irradiating time), and 20 seconds of UV irradiating time. To verify the fabrication uniformity of resin microlenses in large-area, the whole fabricated area were divided into nine areas. The surface profiles of 270 microlenses (30 microlenses were randomly selected in each area) from a single process run are measured. As shown in Table 1, the average diameter is 119.77µm with a standard deviation of 1.73µm, while the average sag height is 7.89µm with a standard deviation of 0.47µm. The small deviation shows that the high uniformity over whole large area has been achieved. Results proves that the potential of this process for fabricating large-area microlens array.

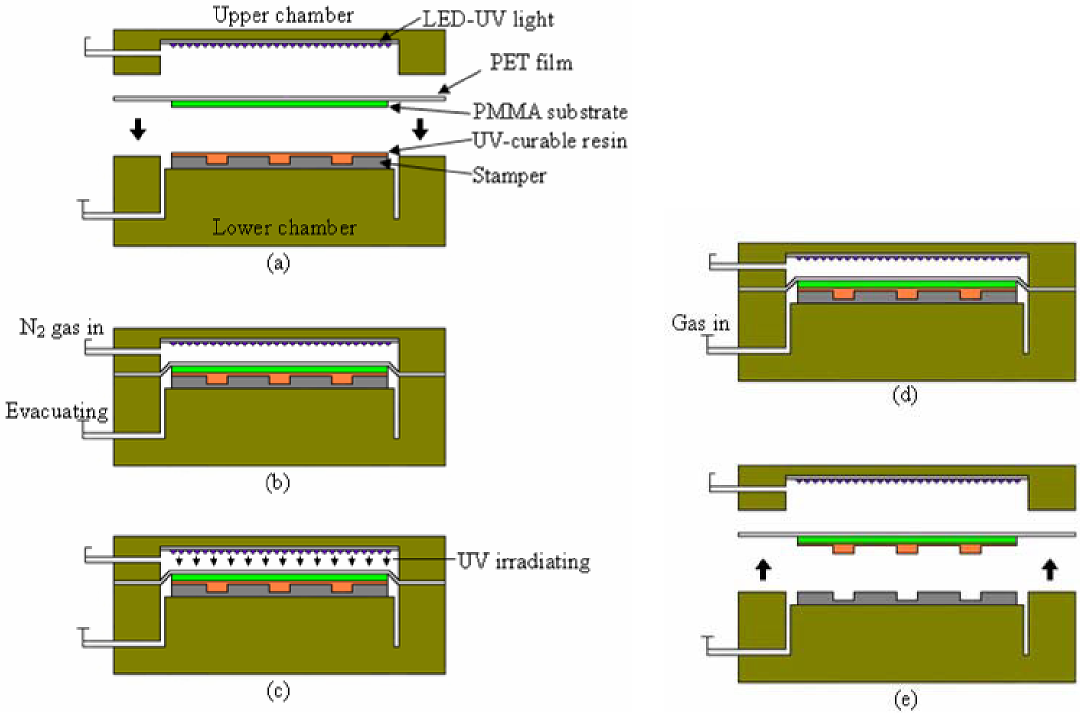

Fig. 1. Schematically showing the gas-assisted UV-curing embossing process.

Fig. 2. Photograph of the UV-LED array(14 x 9) lamp.

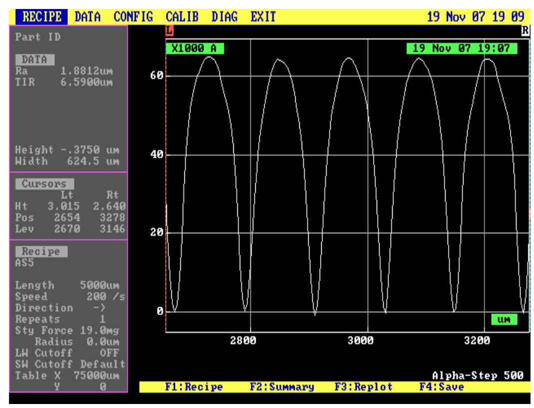

Fig. 3. Surface profile of the fabricated microlens array on PMMA substrate.

Table 1. Large-area uniformity of fabricated microlens array.

Area	Average diameter (μm)	Standard deviation for diameter (μm)	Average height (μm)	Standard deviation for diameter (μm)
No. 1	118.780	1.400	7.761	0.371
No. 2	119.500	1.265	8.124	0.353
No. 3	119.930	2.496	7.990	0.370
No. 4	120.100	1.835	7.548	0.359
No. 5	120.100	0.001	7.896	0.527
No. 6	120.100	2.089	7.907	0.427
No. 7	119.260	1.332	7.932	0.378
No. 8	120.004	1.310	8.030	0.727
No. 9	120.3	2.419	7.733	0.300
Total area	119.770	1.733	7.886	0.467