Fabrication of Dual-Focus Microlens Array by Using Dynamic Optical Projection Stereolithography

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Abstract: A new optical fabrication technology for fabrication of dual-focus microlens array is presented. We experimentally demonstrated that the surface of microlens can be precisely tailored by the technology to engineer the focal structure of microlens.

OCIS codes: (220.4610) Optical fabrication; (220.3630) Lenses; (220.3740) Lithography.

Microlens arrays (MLAs) are one kind of fundamental elements in micro-optic systems and are widely used in optoelectronics, optical communications, and integrated optics [1]. Dual-focus microlens, which contains two focal points, has extensive applications in beam shaping, optical storage, and sensing systems [2]. Here, we present a new optical fabrication technology for rapid printing of dual-focus microlens arrays (DFMLAs). An in-house dynamic optical projection stereolithography setup, which was demonstrated for fabrication of optical microresonators [3], sensors [4], and 3D microstructures [5, 6], was used to precisely tailor the surface of microlens so as to develop dual-focus microlens arrays for engineering the focal structure of microlens.

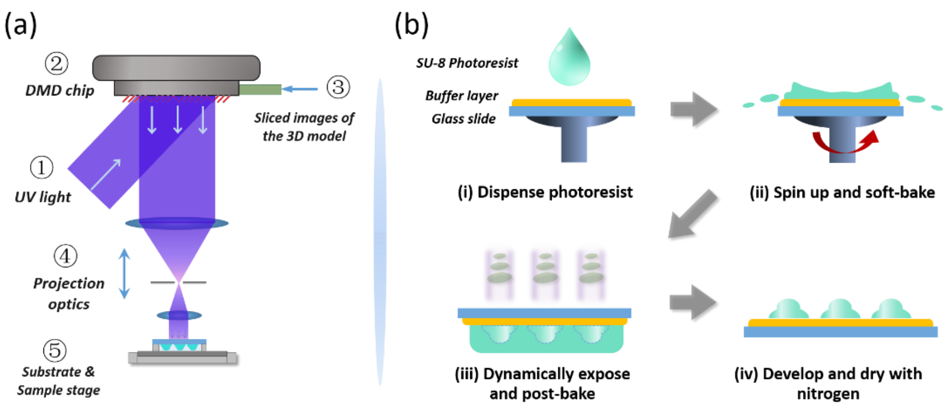

Fig. 1 (a) Schematic diagram of the optical fabrication setup. (b) Fabrication processes for printing of microlens array: (i) SU-8 photoresist is dropped on a glass slide with buffer layer; (ii) the photoresist is spin-coated and then soft-baked to remove solvent; (iii) the photoresist is dynamically exposed. (iv) the sample is post-baked and then developed with PGMEA.

Figure 1 shows the dynamic optical projection stereolithography technology and the processing flow for fabrication of microlens array. Collimated UV light illuminated the DMD chip, which created a series of optical patterns according to the image data sliced from a 3D modal. The SU-8 photoresist spin-coated and pre-baked on a glass slide was inversely placed (i.e. upside-down) on a mount. The optical patterns were then dynamically projected through a set of lenses onto SU-8 photoresist to construct microlens arrays with predefined surfaces.

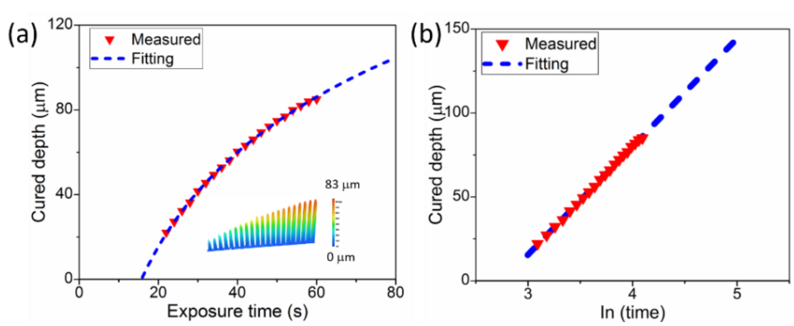

Fig. 2 (a) Dependence of the cured depth of SU-8 on exposure time. The inset is the laser-scanning confocal 3D image of SU-8 micro-pillars fabricated with different exposure doses. (b) Cured depth versus logarithm of time.

The relationship between the cured depth in photoresist and exposure time was characterized by a trail fabrication of micro pillars. As shown in Fig. 2, the cured depth increases logarithmically with the increase of exposure time. The UV light intensity used for the exposure experiments was 41.15 mW/cm^2. The slope of cured-depth line depends on the concentration of photoinitiator. Fig. 3 shows the fabricated MLAs with different surfaces. The diameter of single-focus microlens shown in Fig. 3 (a) is 184.1 μm, while the diameters of the dual-focus microlens shown in Fig. 3 (b) and (c) are 289.2 and 188.4 μm, respectively. The diameter of the upper lens of the dual-focus microlens shown in Fig. 3(c) is 120.1 μm, and the diameter of the upper lens shown in Fig. 3(d) is 50.8 μm.

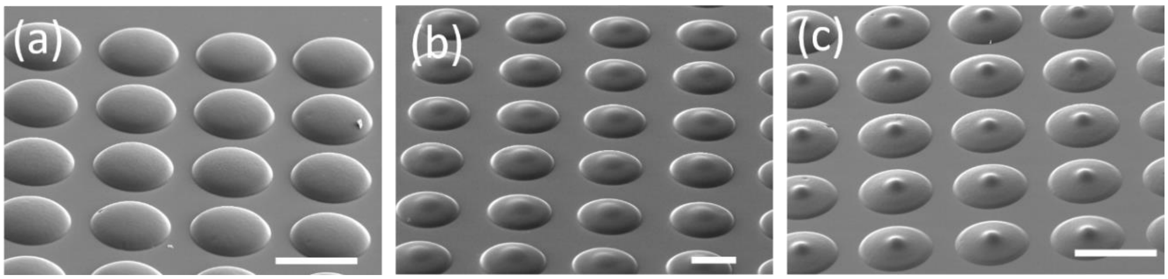

Fig. 3 SEM images of the fabricated microlens arrays: (a) single-focus microlens; (b, c) dual-focus microlens. Scale bar is 200 μm.

The measured and simulated focal lengths of the microlens shown in Fig. 3(a) are 910 and 921 μm, respectively, as shown in Fig. 4 (a). For the dual-focus microlens shown in Fig. 3(b), the measured first and second focal length are 405 and 880 μm, respectively. It agrees well with the simulation results of 404 and 865 μm, respectively. For the dual-focus lens shown in Fig. 3 (c), the measured first and second focal length are 265 and 1510 μm, respectively. The simulation results of the two focal lengths are 274 and 1487 μm, respectively.

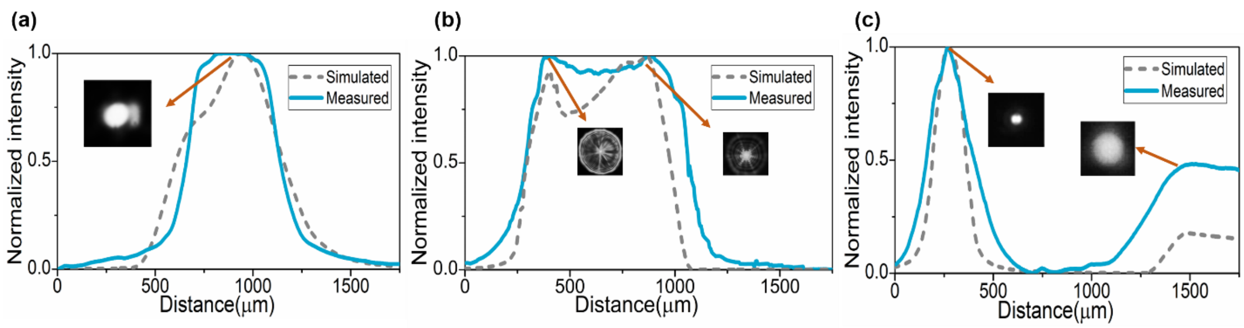

Fig. 4 Focus optical properties and simulation results. (a) the focal property of single-focus microlens (b)the focal property of DFMLAs with 120.1-μm diameter upper lens. (c) the focal property of DFMLAs with 50.8-μm diameter upper lens. The insets are images of focal points.

In summary, we have presented a new fabrication technology for fabrication of both single-focus and dual-focus microlens arrays. Both experimental and theoretical results have been demonstrated to reveal the elongated focal depth and even two distinct focuses of the special microlenses.

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