Fabrication and characterization of microlens array manufactured from microfluidic chip

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Abstract

The paper presents a novel manufacturing process for microlens arrays (MLA). This process used micro machining, double-sided PDMS casting, and plasma bonding to create a hybrid microfluidic chip for manufacturing an MLA on a PDMS substrate. Compared to other reported methods for MLA, this method is rapid, cost-efficient, and capable of manufacturing MLA with various physical dimensions, including sag height and curvature, on a single substrate. The fundamental idea of this method is to deform the PDMS membrane by changing the hydraulic pressure inside the microchannel. Experiment were realized to understand the relationship between the hydraulic pressure inside the microchannel and the deformation of PDMS. And to characterize the uniformity of the MLA, an automatic optical system was built to measure the focal length and curvature of each microlens.

Keywords: Microlens Array, Microfluidics, Micromilled Microfluidic Devices

1. Introduction

Expansive growth in the optoelectronic industry and intelligent manufacturing is fueling interest in methods for the efficient fabrication of precise optical components. Microlens arrays (MLAs) are widely applied in optical communication [1], flat panel display modules [2]. Numerous fabrication methods have been developed for the fabrication of MLAs on polymeric substrates, including photoresist reflow [3], gray-scale photolithography [4]. A number of researchers have integrated adjustable microlenses into microfluidic platforms. Chronis et al. [5] reported an elastomer-based tunable liquid-filled microlens array fabricated using soft lithography, in which the focal length of the microlenses is pneumatically controlled via a microfluidic network to pressurize each microlens evenly.

2. Fabrication process

Figure 1 illustrates the concept underlying the proposed fabrication process. Figure 1(a) shows the micromilled 1st mold insert on a PMMA substrate and Figure 1(b) shows the PDMS casting as the 2nd mold inserts used in the fabrication of the PDMS membrane. A cast PDMS membrane was formed from the micromilled PMMA substrates and subsequently bonded to a glass substrate with the aid of plasma treatment (Figure 1(c)). Liquid is injected into the microchannel of the glass-PDMS microfluidic chip, such that the pressure accumulating within the chamber causes the PDMS membrane to deform into a spherical shape (Figure 1(d)). The deformed PDMS membrane is used as a 3rd mold for UV adhesive casting. The degree to which the PDMS deforms is easily controlled by adjusting the pressure inside the micro chamber. UV adhesive is poured over the membrane and quickly hardened under exposure to UV radiation for use as a 4th mold in subsequent PDMS casting (Figure 1(e)). In the final step, the PDMS casting is used to transfer the spherical concave shape from the UV substrate to the PDMS substrate (Figure 1(f)). Figure 2 shows the MLA on a PDMS substrate with diameters of 1000 μm.

3. Methods

Two experiments were conducted to characterize the MLA, including the following: (1) use an automatic optical system to measure the focal length and curvature of each microlens. Figure 3(a) shows the layout of the optical system and Figure 3(b) shows the setup. The laser light will penetrate through the beam expansion system and MLA, and a CCD image module located from the other side will capture the image of the MLA for further analysis; (2) a system was used to understand the relationships among membrane thickness, pressure, sag height, and focal length. Figure 4 shows the setup of the experiment.

4. Results and Conclusion

Figure 5 shows the captured image from the optical system, which will be used to quantify the uniformity of the MLAs; (2) the sag height of the MLAs can be easily adjusted by changing the hydraulic pressure inside the microchannel, which led MLAs with different sag height and curvature.

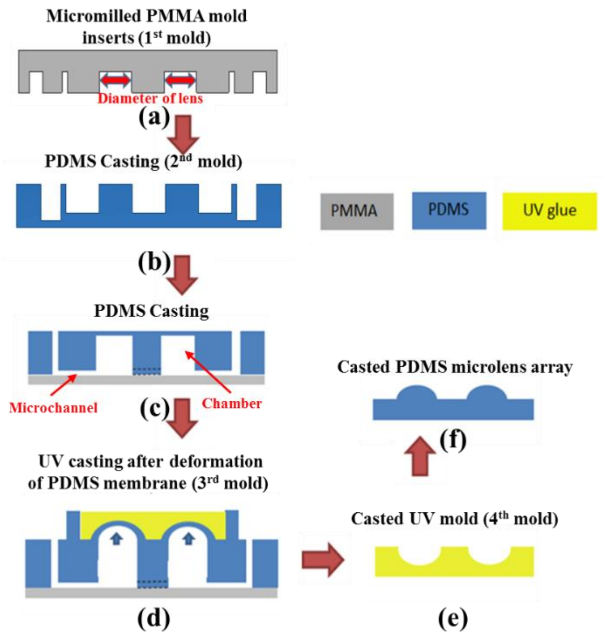


Figure 1: Conceptual diagram of proposed fabrication process in 2-dimension.

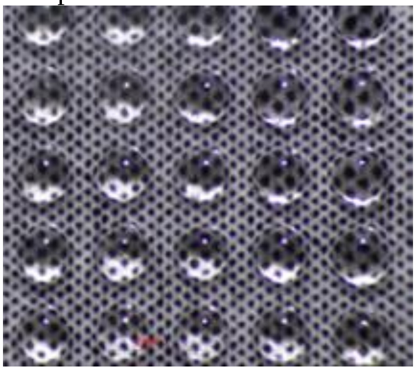
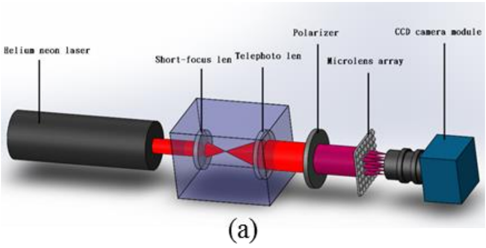
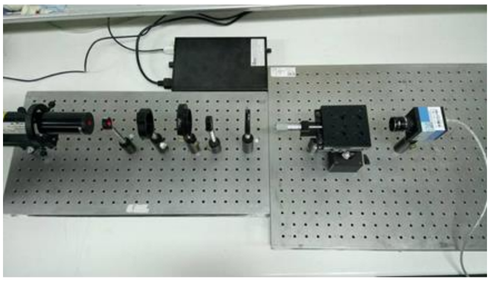


Figure 2: the MLAs on a PDMS substrate with diameters of 1000 μm



(a)



(b)

Figure 3: (a) the layout of the optical system used to measure the uniformity; (b) the real setup of this system for experiment.

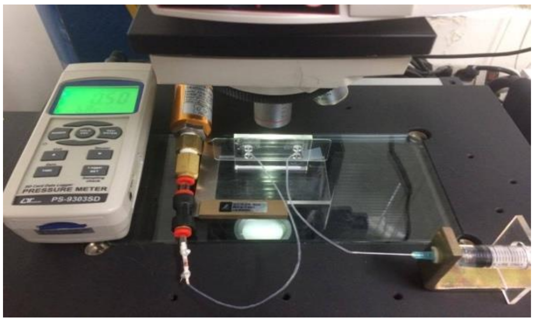


Figure 4: the experiment setup to measure the relationships among membrane thickness, pressure, sag height, and focal length.

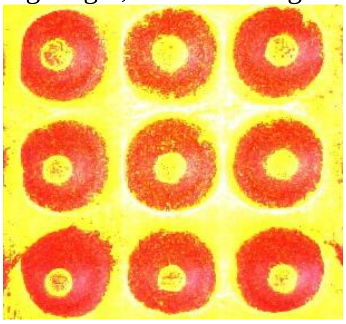


Figure 5:Captured image of the MLAs from the automated optical system, which will used for estimate the uniformity.

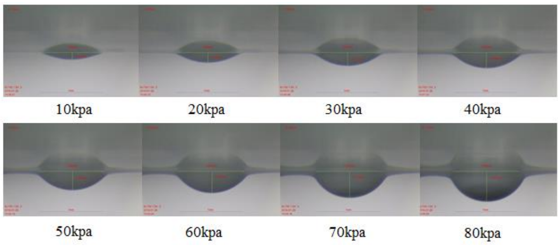


Figure6: Cross-section images of MLA showing different sag heights as a function of pressure.

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