Fabrication of adjustable microlens on hemi-sphere PMMA substrate

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Introduction

Microfluidics has been developing for two decades, and most of the microfluidic applications were developed on flat microfluidic platforms. In this study, we used a 3-axis micromilling machine, which was commonly used in many laboratories and factories, to manufacture adjustable microlens on three-dimensional substrates. From the experiments, it is clear that several factors were critical to the quality of the micro features on the three-dimensional substrate, including the plan of the cutting path, the profile of the cutting tool, and the depth of cut. After carefully planning the cutting path with UG software and accumulating experience, we could successfully manufacture precise micro features on a three-dimensional polymeric substrate, which could be bonded with another piece of polymeric substrate by solvent bonding or used as a mold insert to fabricate micro features on the PDMS substrates by PDMS casting technique. To clearly demonstrate this fabrication process, we designed and fabricated an PDMS-based adjustable microlens on semi-sphere PMMA substrate and red food dye was used to show there had no leakage after bonding.

Background

With the increasing demand of microfluidic-based applications, the geometry of microfluidic is getting complex. Except microchannels on the flat substrates, the fabrication technologies of three-dimensional microchannel have been introduced and developed. Yang Liao et al. [1] used femtosecond laser to directly create three-dimensional microchannels on glass substrate. Casey C. Glick et al. [2] employed a 3D printer to fabricate the three-dimensional mold insert, in which the micro features were transferred to PDMS substrates by PDMS casting technique. Janelle R. Anderson Jo et al. [3] reported a method called “membrane sandwich”, in which a thin membrane had microchannel structures on both surfaces and had holes through the substrates, then these two flat and thick slabs were used to sandwich this thin membrane and became a complete chip. In this study, we utilized a rapid and cost-efficient 3-axis micromachining to fabricate adjustable microlens on three-dimensional substrates as a demonstration.

Fabrication Procedure

To fabricate PDMS-based microlens on a three-dimensional PMMA substrate, two PMMA mold inserts were fabricated with the micromachining and they are shown in the Figure 1. In the Figure 1, the left side is the top mold insert and the right side is the bottom mold insert, both were created on PMMA substrates with a ball-shape cutting tool. Once these two mold inserts were ready, aligned, and assembled, a PDMS casting technique was used to fabricate a thin PDMS membrane with micro features on it between these two mold inserts. Then this PDMS membrane would be bonded with a semi-sphere PMMA substrate by plasma assisted solvent bonding [4], shown in Figure 2. To investigate the bonding quality and the bonding strength, a system was built up and shown in Figure 3.

Experiment Results

With this technique, we successfully fabricated an adjustable PDMS microlens on a hemi-sphere PMMA substrate. Figure 4 shows the top view of this adjustable microlens and no leakage was observed. Figure 5 shows the side view of this adjustable microlens and it is clear that microlens were created when the red food dye was pushed into the microchannel and caused the PDMS membrane to deform. With this technique, more complex microfluidic chips could be created to satisfy the demand of microfluidics chips on various applications.

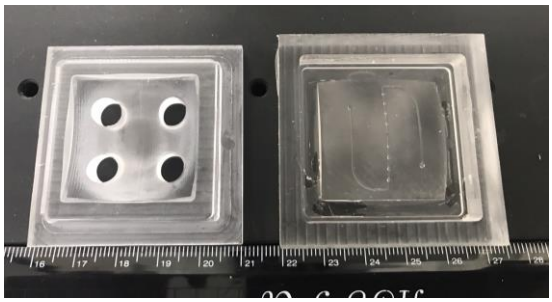

Fig.1: The mold inserts with fabricated micro features on three-dimensional PMMA substrate, which was used for fabricating PDMS membrane.

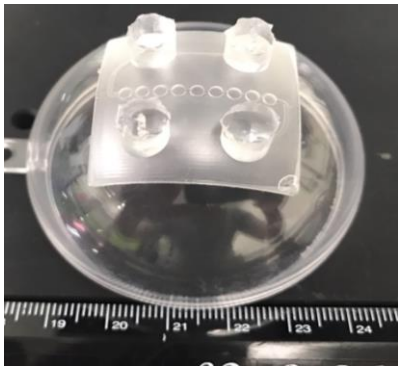

Fig. 2: PDMS membrane was bonded with a semi-sphere PMMA substrate by plasma assisted solvent bonding.

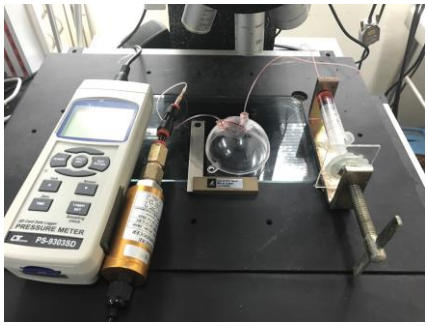

Fig3. A system was built up to investigate the leakage while measuring the bonding strength simultanesously.

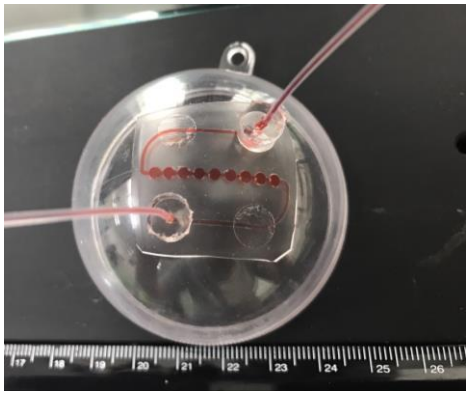

Fig4. Top view of an adjustable microlens on a hemi-sphere PMMA substrate. It is clear that no leakage was observed.

Fig5.Side view of the adjustable microlens on the hemi-sphere substrate.

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