MICROFABRICATION OF ROUNDED CHANNEL AND WAVEGUIDE INTEGRATED MICROLENS USING TIMED DEVELOPMENT AND THERMAL REFLOW PROCESS

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ABSTRACT

Timed development and thermal reflow processes have been utilized for the fabrication of rounded microfluidic channel and microlens. The curvature or the sphericity can be predicted by microfluidic surface mechanics and the meniscus profile derived from the Young-Laplace equation. Microfluidic channels with rounded walls, microlenses, and waveguide integrated microlenses are successfully demonstrated as test vehicles.

KEYWORDS: Timed development, Thermal reflow, Rounded channel, Sphericity, Microlens

INTRODUCTION

Despite the many advantages and potential applications of microstructures with a round shape profile, such as a microchannel with rounded top/side walls [1] and an integrated lens with a parabolic cross-section, their implementation is quite challenging in microfabrication. In this research, a fabrication process using timed development in the deep via pattern of ultraviolet (UV) lithography with SU-8 and subsequent thermal reflow has been demonstrated to achieve rounded profiles for such microstructures. Fabricated concave patterns are micromolded to produce a convex replica if appropriate. This process provides unique properties: (1) top/bottom curvature is accurately controlled by using microfluidic surface mechanics, (2) the rounded top/bottom combined with a straight side wall can be simultaneously formed by development time control, (3) structures with different heights can be simultaneously fabricated in a single development step, and (4) the process can be further combined with advanced multidirectional UV lithography [2] to form microstructures with a tilted side wall and a rounded top/bottom.

THEORY

The curvature of the reflow meniscus is calculated using an equation derived from the Young-Laplace equation [3].

$$\left(\frac{h_m}{a}\right)^2 = 1 - \sin\theta \qquad (1)$$

where h_m, a, and θ are the meniscus height, the capillary constant, and the contact angle, respectively. Capillary constant is calculated from the radius of the meniscus and the capillary length [2]. As development proceeds in the via, the resultant contact angle also varies as shown in Figure 1(a), such as a spherical shape, a parabolic

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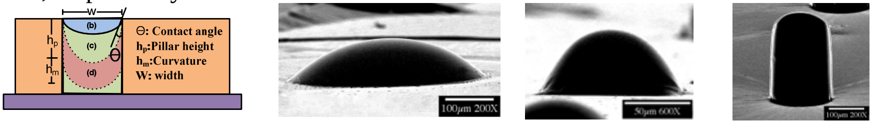
shape, and a parabolic shape with an extended straight side wall as shown in b, c, and d, respectively.

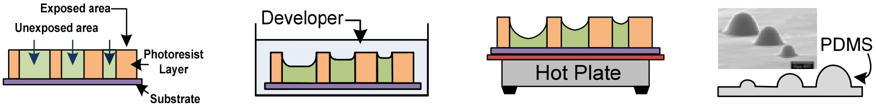


(a) (b) (c) (d)

Figure 1. Different sphericity of the resultant meniscus: (a) Schematic of sphericity, (b) Spherical shape, (c) Parabolic shape, (d) Spherical shape integrated with a vertical waveguide

FABRICATION PROCESS

As shown in Figure 2, SU-8, negativetone photoresist, is coated, followed by softbake, UV exposure (LS 30/5, OAI Inc.), and post exposure bake steps. The uncrosslinked polymer of the via pattern is developed using propylene glycol monomethyl ether acetate (PGMEA) in a time controlled manner without stirring (2b). The sample is baked at 95°C for an hour for thermal reflow and cooled down to room temperature to form a concave parabolic curvature at the bottom (2c). Additionally polydimethilsiloxane (PDMS) can be applied on the concave structure to obtain a replica of a convex shape (2d).



(a) (b) (c) (d)

Figure 2. Fabrication process: (a) Patterned SU-8 after post exposure bake, (b) Timed development, (c) Thermal reflow, (d) Micro convex structures

RESULTS AND DISCUSSION

Figure 3 shows the development depth for different via opening sizes as a function of development time of 10, 20, and 30 min. The wider the via opening size, the deeper it developed. Figure 4 shows tilted structures with rounded top/bottom resulting from the combination of this process with the multidirectional UV lithography scheme. Figure 5 shows that photomask patterns with various width produce rounded channels with varying heights after molding. Also, an intensity measurement scheme has been applied to get a round shape channel profile in Figure 6. A convex and concave lens, and an array of the lens integrated waveguide are shown in Figure 7(a), (b), and (c), respectively.

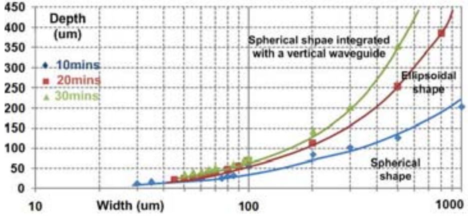
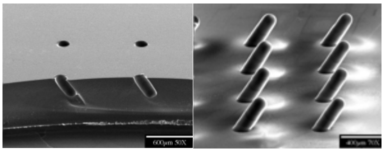
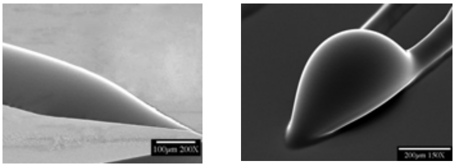


Figure 3. Developing depth as functions of developing time and the opening size of via



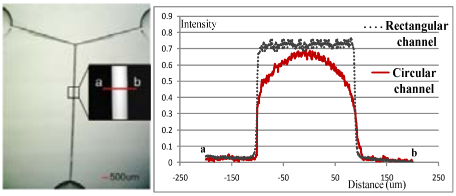
(a) (b)

Figure 4. SEM of tilted patterns: (a) Tilted via hole with rounded bottom, (b) Tilted waveguide with a round tip after replica molding



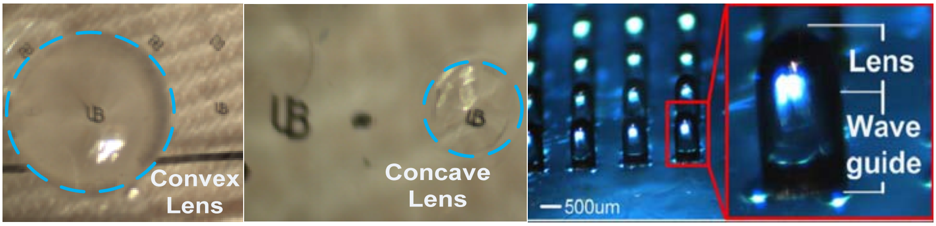
(a) (b)

Figure 5. SEM images of micromolded replicas for microfluidic channel applications: (a) Mold with a tapered height along with tapered channel width, (b) Mold for micro fluidic mixing chamber with a round side wall and a tapered height.



(a) (b)

Figure 6. Intensity comparison between Rounded and rectangular channel: (a) Optical image of a channel, (b) Intensity graph



(a) (b) (c)

Figure 7. Integrated PDMS microlens: (a) Convex lens showing magnified character, (b)Concave lens showing demagnified character, (c) Waveguide integrated microlens array

CONCLUSIONS

Timed development and the thermal reflow processes have been explored for rounded or spherical microstructure fabrication. The concave or convex type as well as the lens integrated pillar type are simultaneously fabricated with different curvatures or sphericities without multi-exposure or alignment for microfluidic and optical MEMS applications.

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