PLASTIC MASTERS – RIGID TEMPLATES FOR SOFT LITHOGRAPHY

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ABSTRACT

We demonstrate a simple process for the fabrication of rigid plastic master molds for soft lithography directly from (poly)dimethysiloxane devices. Plastic masters (PMs) provide a cost-effective alternative to silicon-based masters and can be easily replicated without the need for cleanroom facilities. We have successfully demonstrated the use of plastics micromolding to generate both single and dual-layer plastic structures, and have characterized the fidelity of the molding process. PMs provide a facile technique for the fabrication of microfluidic devices and a simple route for the scaling-up of fabrication of robust masters for soft lithography.

KEYWORDS: polyurethane, master, molding, replication

INTRODUCTION

Soft lithography has emerged as the dominant technique for rapid prototyping of microfluidic devices as miniaturized platforms for experiments in biology and chemistry. Soft lithography employs the casting of elastomeric materials such as (poly)dimethylsiloxane (PDMS) and room-temperature vulcanizing (RTV) silicones on master molds fabricated from photoresists on silicon substrates [1]. These silicon-photoresist masters (SPMs) offer excellent resolution (~1 μm) and allow for multilayer fabrication, but critically suffer from delamination at the photoresist-silicon interface (especially when using the negative-tone photoresist SU-8 [2]). This failure-prone resist-substrate interface results in a master with limited casting lifetime. To overcome this limitation, we have developed a simple process for the fabrication of plastic master molds for soft lithography directly from PDMS devices.

Plastic masters (PMs) provide a cost-effective alternative to silicon-based masters and can be easily replicated without the need for cleanroom facilities. While polymer molding has been previously employed in the generation of masters for soft lithography, most notably in the use of UV-curable epoxies such as Epotek and NOA [3], the fidelity of these UV-cured masters (UVMs) has not been described. Furthermore, two capabilities possible with PMs - the generation of integrated world-to-chip connections and the ability to self-replicate - have not been previously reported for UVMs. Our technique offers further advantages over UVMs in that – (1) they do not require UV-curing systems or lamps and can be readily produced in any lab that already employs soft lithography, (2) the PM fabrication process is performed at room temperature and hence the generation of large-area masters does not require additional process optimizations such as adjusting UV dosage which would be required in the case of UVMs, and (3) PMs can be fabricated at the fraction of the cost of UVMs and hence provide a more cost-effective route for scaling-up master fabrication.

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EXPERIMENTAL

PMs are fabricated using a commercially available two-part polyurethane plastic (Smooth Cast 310, Smooth-On Inc.). Detailed fabrication techniques have been previously described [4]. Briefly, the silicone device to be molded is first affixed to the bottom of an open-topped container constructed of PDMS (Sylgard 184, Dow Corning) using double-sided tape. The container is then placed in a degasser for at least 30 minutes. In the meantime, the polyurethane plastic pre-cursors (parts A and B) are measured out in equal volumes and degassed separately for approximately 20 minutes. Parts A and B are then mixed together slowly taking care to avoid generating bubbles. The PDMS container with affixed device is removed from the degasser and the liquid plastic pre-cursor mixture is poured in. Air bubbles entrapped in device features are removed using a fine wire. Upon curing for 2 hours at room temperature the PM is removed from the container. A simplified process flow is schematically depicted in Figure 1A. The use of an open-topped molding container results in a PM with an integrated trough in which PDMS is cast. In contrast, SPMs have a flat surface with raised features. In some cases, such as the generation of PMs for spin-casting PDMS/RTV and for elastomeric stencil fabrication, it is important that PMs have raised features and no molding trough. These “raised” PMs resemble a conventional SPM (Figures 1C & E).

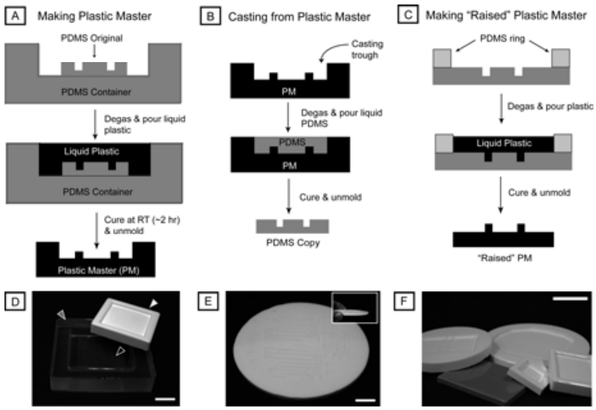

Figure 1. (A) PM fabrication procedure. (B) PM casting procedure. (C) “Raised” PM fabrication procedure. (D) Images of fabricated plastic master (white arrowhead), PDMS container (gray arrowhead) and affixed PDMS device (black arrowhead). Scale bar 35 mm. (E) PM for spin-casting fluidic devices. Scale bar 15 mm. (F) Collection of PMs. Scale bar 50 mm.

RESULTS AND DISCUSSION

Various microfluidic topologies have been successfully reproduced as PMs as shown in Figure 2. Microfluidic devices ranging from standard single-layer multiple-input channels (Figure 2A), serpentine channels (Figure 2B), micro-post arrays (Figure 2C) and micromixers (Figure 2D) have been successfully reproduced as PMs. The micro-post arrays, especially, provide a more robust alternative to similar features replicated in photoresist, which are prone to delamination during PDMS molding. Creating a monolithic master eliminates the common failure mode in SPMs whereby the tall and narrow photoresist posts delaminate from the silicon wafer during molding. The SEM images show excellent fidelity in reproduction from PDMS originals and exhibit sharp side-walls.

We used a standard photolithographic resolution test target (USAF 1951) to fabricate an SPM (using SU-8) and then formed a PM from that master (via PDMS). The SPM and PM were then imaged via an SEM to compare fidelity [4]. SEM images show slight shrinkage (~ 4 %) of the PM features with respect to the original SPM. This shows that PMs provide resolution comparable to SPMs (and would faithfully replicate even the smallest features realized with SPMs, typically ~ 1 μm).

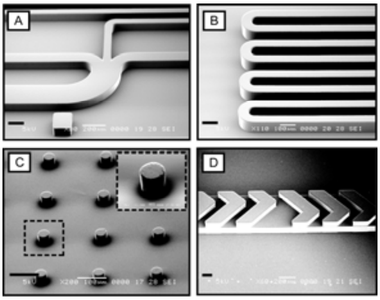

Figure 2. Microfluidic topologies reproduced as PMs, standard single-layer multiple-input channels (A) and serpentine channels (B). (C) Arrays of micro-scale posts, inset shows high magnification view of a single post. (D) Two-level structures have also been successfully replicated. Scale bars 100 μm.

CONCLUSIONS

We have presented a simple, cost-effective technique for the fabrication of rigid plastic masters for the use in soft lithography. This technique allows for the easy creation of robust monolithic molds that faithfully reproduce micron-sized features and are suitable for repeated casting without the need for silanization or other surface pre-treatments. PMs can create monolithic three-dimensional structures from the size scale of microns to centimeters, a feat that is difficult to achieve with either photolithography-based microfabrication or conventional machining techniques.

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REFERENCES

[1] Y. Xia and G. M. Whitesides, Soft Lithography, *Angew. Chem., Int. Ed.*, 1998, **37**, 551-553.

[2] H. S. Khoo, K -K. Liu, and F -G. Tseng, Mechanical strength and interfacial failure analysis of cantilevered SU-8 microposts, *J. Micromech. Microeng*, 2003, **13,** 822–31.

[3] X. Jiang *et al.*, Controlling Mammalian Cell Spreading and Cytoskeletal Arrangement with Conveniently Fabricated Continuous Wavy Features of Poly(dimethylsiloxane), *Langmuir*, 2002**, 18**, 3273-3280.

[4] S. P. Desai, D. M. Freeman, and J. Voldman, Plastic Masters – Rigid Templates for Soft Lithography, *Lab Chip*, 2009, **9**, 1631-1637.