ONE-STEP INJECTION MOLDING OF OSTE+ MICROFLUIDIC DEVICES WITH SCREW THREADED PORTS

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ABSTRACT

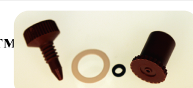
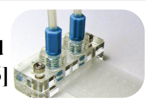
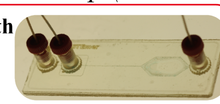
We present a simplified method for molding internally threaded fluidic ports in microfluidic devices using a deformable mold and dual-cure OSTE+ polymer. We demonstrate a lab-on-a-chip device where monolithically integrated chip-to-world threaded interfaces, vias and microchannels are reaction injection molded in one single step.

KEYWORDS: reaction injection molding, OSTE+, microfluidics, lab-on-a-chip, threaded ports, microfluidic interfacing, chip-to-world interface

INTRODUCTION

Microfluidic chip-to-world interfaces include through-holes (simple but unreliable), luer connections (standardised but designed for low pressure) and threaded ports (designed for high pressure) [1]. Traditional molding of threads in plastics requires a wire screw mold insert to be un-screwed after the polymer solidification. Other solutions include relocating the parting line or adding external side-cores/internal core lifters [2]. All these solutions raise manufacturing costs and require long fabrication time and manual operation. Today, the commercially available microfluidic high-pressure ports, e.g. Nanoports (Upchurch Scientific), require gluing which may lead to chemical contamination, leakage and the risk of channel blocking with adhesives (Table 1).

Table 1. Comparison of commercial NanoPort™, thermoset plastic chip and OSTE+ chip (this work)

Port Material	NanoPort™ 	Thermoset Plastic chip with threaded port molding[1,5,6] 	OSTE+ chip with threaded port molding 
Molding	Injection molding with threaded inserts	Injection molding, thermal fusion bonding	Reaction injection molding, Room temperature bonding
De-molding	De-molding machine required	De-molding machine, thread insert, or screw moulding extruder required	Simply pull out/peel off from PDMS mold
Assemblies	Microfluidic chip, nut, port, gasket, adhesives, tubing. Per-part alignment required	Thermoset chip, nut, tubing. Alignment required during mold fabrication (expensive)	OSTE+ chip, nut, tubing. Alignment only required during mold fabrication
Cost	High	High	Low
Contamination	Risk for adhesive contamination	Risk for screwing debris	No contamination
Chemical inertness	Depends on chip material	Some of the thermoset plastics cannot bear harsh solutions	High chemical resistance
Leakage	Depends on adhesion strength, leakage can be observed	Leakage-free	Leakage-free
Pressure Range	103 bar within connector itself	156 bar within chip and connectors	>8 bars within chip and connectors (setup pressure limit)
Biocompatibility	Heat required for ports bonding no biomolecules before bodning	Heat required for chip bonding, no biomolecules before bonding	Room temperature chip bonding, allows surface biofunctionalization before bonding

We previously introduced a dual-cure off-stoichiometry thiol-ene-epoxy (OSTE+) material whose epoxy reactive surface (after the first cure) allows unassisted room temperature bonding [3], and we showed its potential for reaction injection molding [4]. The material has rubbery properties after the first cure but inert and rigid mechanical properties and high-pressure resistance and harsh solvent compatibility after the second cure [4].

Novel approach: using a deformable mold (PDMS) and a replica material (OSTE+) with rubbery properties during demolding, i.e. before gaining its final, stiff, properties, allows for easy molding/demolding by simply pulling (Figure 1).

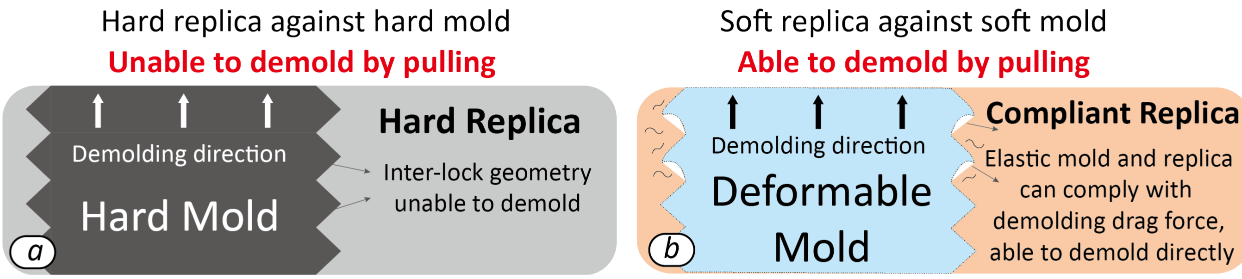


Figure 1. Comparison of undercuts molding PROBLEM in traditional way (a), and our SOLUTION (b)

MANUFACTURING

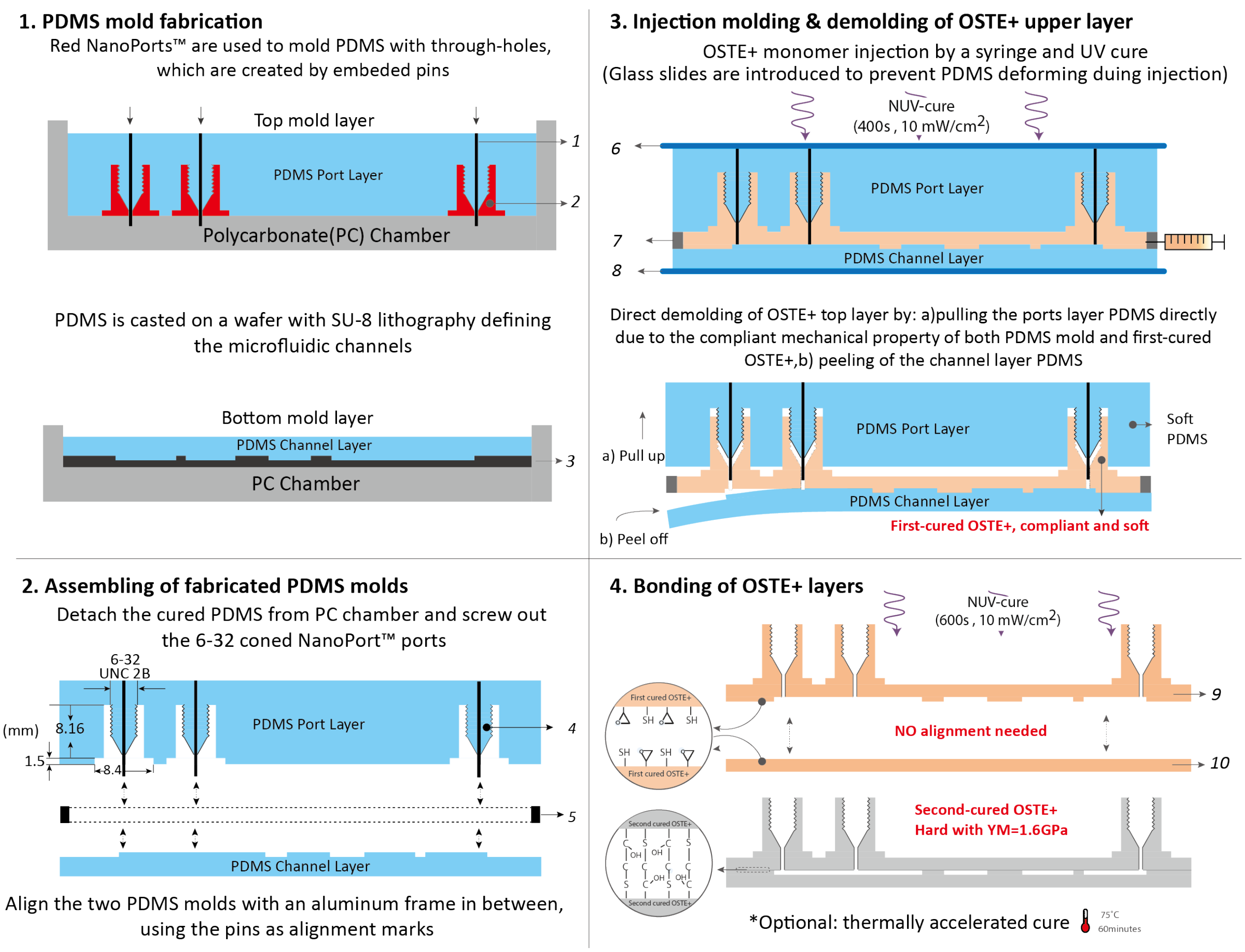


Figure 2: Fabrication protocol for OSTE+ chip. Legend: 1) OD=0.8mm metal pins; 2) Coned port from NanoPort™; 3) Silicon substrate with SU-8 pattern; 4) PDMS thread molded from ANSI 6-32 coned NanoPort™; 5) 1mm thick hollow aluminum spacer; 6&8) Glass slides; 7) Aluminum spacer; 9) First-cured OSTE+ upper layer; 10) Another first-cured OSTE+ featureless bottom layer.

PDMS mold fabrication: 1) A top PDMS mold with thread-undercuts was casted around a commercial PEEK coned NanoPort 6-32 (Upchurch Scientific) of which the ports with OD = 0.8 mm were anchored with metal pins at the I/O sites during the curing process and subsequently de-molded by screwing the ports anti-clock wise. Another bottom PDMS mold was casted from a silicon wafer with SU-8 lithography to bear desired microfluidic channel patterns.

Reaction injection molding: 2) OSTE+ with 50% thiol excess (1:1.5:0.5 for ally:thiol:epoxy, with TPO-L as first-cure initiator and an anionic photo-latent curing agent provided by BASF as second-cure initiator) was injected in aluminum/PDMS molds with glass slides clamped on both sides to prevent PDMS deforming. 3) Collimated UV exposure (OAI Model 30 UV Light Source) triggered the first cure, leaving unreacted thiol and epoxy. 4) PDMS molds were removed from both sides simply by pulling and peeling. 5) The first-cured OSTE+ sheet was bonded with another first-cured featureless OSTE+ layer via second UV curing to seal the chip.

EXPERIMENTAL EVALUATION AND DISCUSSION

We evaluated the port connections using visual inspection and using a blister pressure test to verify the robustness of the interfaces (Fig. 3). The port connection withstood more than 8 bars, which was our current setup pressure limit.

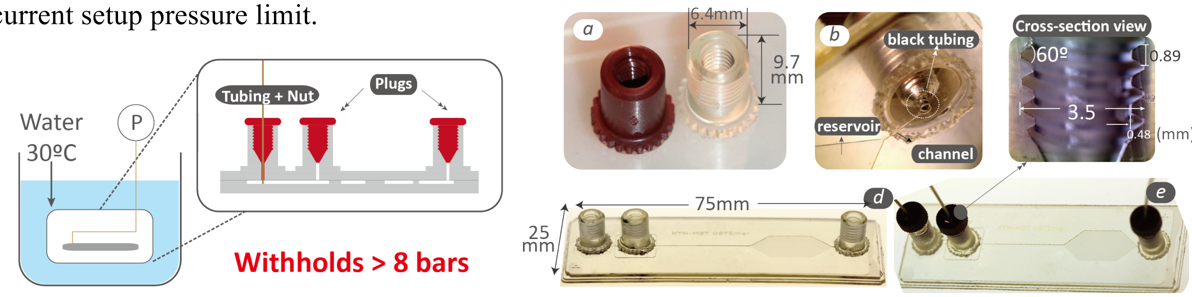


*Figure 3: **Left:** Blister test of fabricated OSTE+ chip in RT water. The chip connection can withhold pressure >8 bars with our current setup measurement limit. **Right:** a) Photograph of NanoPort™ port and OSTE+ port. b) Bottom view photograph of OSTE+ monolithic upper layer with SELF-ALIGNED through-hole and black tubing with ZERO DEAD VOLUME. c) Photograph of an OSTE+ port cross-cut. d) Photograph of an OSTE+ chip with integrated ports, without and e) with fittings and tubing.*

The Advantages presented in this work include: 1) manufacturing of thread-undercuts by direct molding/de-molding exhibits an uncomplicated and rapid manufacturing process with high design flexibility; 2) integrated interfacing with a plug-and-play feature allows > 8 bars pumping pressure and withstands force/torque from any direction; 3) monolithic device upper layer features integrated and self-aligned ports and channels.

CONCLUSION

We presented and successfully tested an uncomplicated, rapid and robust method for manufacturing integrated high-pressure microfluidic ports compatible with commercialized capillary finger-tight fittings. The key enabler of this technology is the combination of: i) a deformable elastomeric mold material (PDMS); ii) a replica material that is soft after molding but stiff after a second UV curing step to withhold high pressure. The elastic deformability of the mold and the replica allows demolding by simply pulling apart mold and replica, without the need for complicated mold insert handling or demolding actions.

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REFERENCES

[1] C. K. Fredrickson et al., "Macro-to-micro..," Lab Chip, vol. 4, no. 6, p. 526, 2004
[2] Online source: http://www.plasticstoday.com/articles/design-molded-threads—part-3
[3] F. Saharil et al., "Dry adhesive bonding...," J. Micromech. Microeng., vol. 23, no. 2, p. 025021, Jan. 2013.
[4] T. Haraldsson et al.,"OSTE: a novel...," SPIE MOEMS-MEMS, vol. 8976, pp. 897608, Mar. 2014.
[5] J. Steigert et al., "Rapid prototyping …," J. Micromech. Microeng., vol. 17, no. 2, pp. 333–341, Jan. 2007.
[6] D.A. Mair et al., "Injection molded…"J. M. J., & Svec, F. (2006). Lab on a Chip, 6(10), 1346–1354.

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