A PDMS PINCH VALVE WITH ZERO DEAD VOLUME AS A VALVING MODULE FOR RIGID POLYMER LAB CHIPS

Andrew W. Browne and Chong H. Ahn
Microsystems and BioMEMS Laboratory,
Department of Electrical and Computer Engineering
University of Cincinnati, Cincinnati, Ohio 45221 USA

ABSTRACT

A new modular dead volume-free PDMS pinch valve for integration into rigid microfluidic chips has been designed, fabricated and characterized in this work for valving and flow regulation on rigid polymer lab chips. Here we combine the benefits of rigid polymers for fluidic devices and flexible PDMS for valving modules to yield hybrid polymer lab chips with integrated PDMS valves that enable both easy valving and precise flow regulation not seen in single polymer lab chips.

KEYWORDS: PDMS pinch valve, zero dead volume, polymer lab chip, fluidic device

INTRODUCTION

Microfluidics demand precise control of fluid movements along channels. Therefore, a wide variety of on-chip valve designs have been developed in PDMS, glass and silicon [1]. Many microfluidic valves are actuated by external controls such as pneumatics [2,3], temperature switches and mechanical deflection which usually limit microvalve operation to simple on/off states requiring sophisticated control schemes. Rigid polymers for microfluidics are attractive because of their, low cost, high volume mass fabrication and chemical resistance. Elastomeric PDMS microfluidics devices enjoy the flexibility of pinch valve actuation at any accessible point along the device [4].

DESIGN AND FABRICATION

Figure 1(a) s the concept of modular PDMS pinch valves bridging underlying interrupted rigid polymer microfluidic channels. 3D assembly of the pinch valve is displayed in Figure 1(b) and pinch valve functionality is extended to flow regulation by precisely controlling the degree of pinch using a control layer overlying a glass bearing that compresses the pinch valve (Fig 1 (c)).

Figure 1. Pinch valves: (a) Modular PDMS pinch valve concept. Bulk fabricated PDMS modules with semicircular channels are inserted into a rigid polymer device to bridge interrupted channels, thereby enabling pinch valving and flow regulation in any rigid polymer device; (b) 3-D assembly of PDMS pinch valve inserted into
rigid polymer device bridging an interrupted microfluidic channel; and (c) Flow regulation may be achieved by placing a bead over the channel and controlling the degree of pinch valve compression by an overlying pocket in an actuation layer.

PDMS pinch channel modules were bulk fabricated using CNC micro-machined molds and 10:1 Sylgard 184 with curing agent at 70 °C for 30 minutes (Fig 2 (a)). Figure 2 (b) outlines device fabrication by injection molding COC microfluidics and pinch valve layers with subsequent insertion and self-aligning of PDMS pinch module with thermal bonding to automatically seal the valves. Figure 3 shows a sample PDMS pinch module, an assembled PDMS/rigid polymer hybrid device and an Environmental SEM (ESEM) of the pinch modules rounded channel geometry which facilitates valve closure.

**Figure 2. Fabrication and valve assembly:** (a) i) CNC machined aluminum molds emboss a polymer, ii) PDMS is poured over polymer molds and the molds are approximated, and iii) Molds are separated and PDMS pinch valve module removed and (b) i) Nickel and aluminum molds are used for injection molding COC microfluidic and pinch valve layers respectively, ii) PDMS pinch valve module is inserted into upper COC layer, and iii) Thermal bonding seals the valve.

**Figure 3. Fabricated device:** (a) PDMS pinch module; (b) Assembled pinch valve. Red dye showing no leakage or dead volume; and (c) ESEM of rounded pinch module’s channel geometry.

**RESULTS AND DISCUSSION**

Actuation of the valve is accomplished by pressing and releasing a bead over the center of the valve channel using an overlying ‘actuation layer’ with micromachined pockets that regulate actuation distance of the glass bearing. Valving is demonstrated by a 4-branched microfluidic channel, each channel containing a pinch valve (Fig 4).

Maximum reliable flow rates are determined by maximum gravity driven flow and quantitation of flow rate for 3 valves with differing valve channel widths (Fig 5 (a)). Flow rates below the maximum flow rate represent flow pressures that do not compress or distort the PDMS modules, thereby avoiding valve failure. Finally, simple and reliable flow regulation was achieved by positioning an actuation layer with different cavity depths above the glass bead (Fig 5 (b) and (c)).
Figure 4. An incoming microfluidic channel splits into 4 valved channels and an overlying actuation layer (clear polymer) is rotated over the microfluidic device to affect sequential opening and closing of 4 pinch valves and channeling red dye to each opened channel.

Figure 5. Measured flow rates: (a) Maximum and minimum flow rates are measured for three PDMS pinch modules with increasing channel width. Maximum flow rate determines the upper bound of flow control without valve failure; (b) Photomicrographs of PDMS pinch channels (black dotted line) in 3 configurations: closed, partially compressed and open; and (c) Graph of flow rate as determined by degree of pinch valve compression.

CONCLUSIONS

These results clearly demonstrate this modular PDMS pinch valve’s abilities as an actuation scheme to effect flow regulation in a simple manner. Bulk fabrication of PDMS pinch modules with easy integration into any rigid substrate for microfluidic applications requiring low dead volume and leakage is both reliable and practical. The new modular PDMS pinch valve developed in this work can have numerous applications for the fluidic control in polymer lab chips.

REFERENCES