

A MICROFLUIDIC SWITCHBOARD

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ABSTRACT

The Microfluidic Switchboard is an array of microvalves and microchannels which create a large scale microfluidic platform that will automate macroscale, bench-top laboratory protocols and package them in low cost, portable lab-on-a-chip systems that can be used for clinical diagnostics, environmental monitoring, pharmaceutical drug discovery and chemical synthesis. This paper describes characterization of actuators for such valves and preliminary design and fabrication of scalable microvalves built entirely on printed circuit board (PCB) material.

Keywords: microvalves, actuators, phase-change material, lab-on-a-chip, PCB

1. INTRODUCTION

The current industrial approach to addressing large scale fluidic manipulation is done using enormous robotic workstations that are bulky, expensive and labor-intensive. There are few reports to create microfluidic multiplexing using pneumatics¹ and binary tree logic² for such applications. Several devices have been created to control fluid flow on the microscale but these are also cumbersome or involve complex fabrication procedures³. The fluidics themselves are compact and able to perform a variety of procedures, but the fluidic valves are actuated using air pressure, which means even more valves. The system of ‘valves controlling valves’ not only means more valves, but an entire air routing system consisting of control channels, valves and a pressure source. It should also be noted that the ability to produce large number of fluidic manipulations by these devices resides in the valve and the control channel layout and often requires a complete change in design for even a small change in a particular fluidic manipulation protocol.

The Microfluidic Switchboard completely eliminates external air routing system by containing less-expensive valves that seal the fluidic channel equally well and actuated with only an electric current. The scalability of these valve units makes it possible to design robust microfluidic devices so that the ultimate complexity and applications of highly dense functional valve elements is nearly endless. The complete package will consist of a small, disposable card with only electrical connections for fluidic control and sample inputs.

2. EXPERIMENTAL

Essentially, this design is a multilayer microfluidic system made of one layer containing fluidic microchannels, a silicone membrane layer, and an actuation layer containing an expanding phase-change-material as shown in Figure 1. The melting of a paraffin wax phase-change material is induced using a joule heating-based in-situ heater and not an external thin film⁴ or optics⁵ based heating mechanism.

The In-situ heater is a composite of paraffin wax and graphite, and requires only electrically conductive traces as the interface. Resistive heating due to the passing of electrical current through graphite powder dispersed in paraffin wax results in melting and

expansion of the wax which in turn expands the thin silicone membrane to induce actuation.

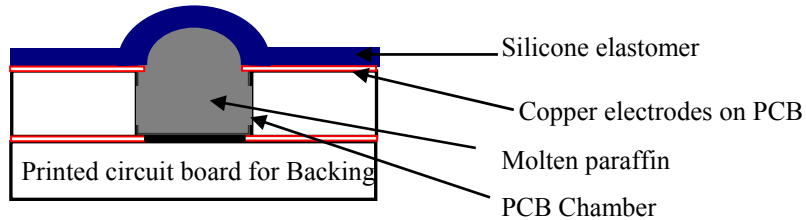


Figure 1 Architecture of the phase-change material based actuator

Valves are created by integrating these actuators with microfluidic channels. Microchannels are created using a thin polymeric liner with press-cure adhesive on both sides. Xurography is used to create the microfluidic channels⁶.

3. RESULTS AND DISCUSSION

The actuation of the valve membrane is done in less than a second at only 0.2 W per valve for $\sim 300 \mu\text{m}$ actuation heights as shown in Figure 2.

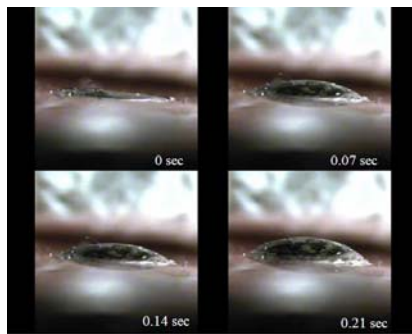


Figure 2. Actuation of the membrane

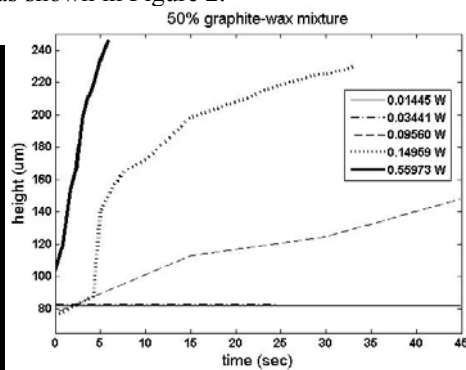


Figure 3. A plot of dot height vs. power and/or actuation time

The use of in-situ heater allows for efficient power usage and very fast actuation. The uniformly dispersed electrically conductive matrix provides a large surface area for heating. Figure 3 shows the typical actuation plots for a 50 % graphite-wax mixture. It can clearly be seen that actuation of $200 \mu\text{m}$ can be achieved very fast and it should also be noted that the typical microchannels are much thinner (close to $100 \mu\text{m}$) and such channels would require much less power and actuation times.

To demonstrate the scalability of these actuators, a medium scale array of 64 individually addressable actuators is built using PCB as substrate as shown in Figure 4. An electronic circuit with the power programming has been developed that can address each actuator individually to maintain certain height of the membrane.

The raising and lowering of the actuator membrane was used to block or open the fluidic channel respectively. Complete blocking of fluid flowing in a pressure-driven channel (with one syringe pushing fluid at the inlet and another drawing fluid at the outlet) was observed when the valves were activated. Arrow in Figure 5 shows the valve area at 0 S.

After the valve activation, as the time progresses vacuum is created just after the valve area indicating the stoppage of the flow downstream of the valve.

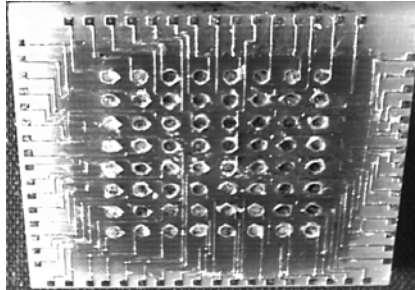


Figure 4. Array of actuators on PCB to be integrated with PDMS microchannels

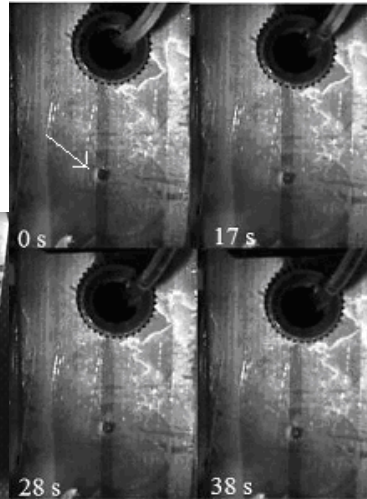


Figure 5. Integration of the actuator with the fluidic channel.

4. CONCLUSIONS

A novel actuation mechanism that can be integrated to microfluidic circuit has been demonstrated and characterized. The performance of this actuator is found to exceed similar devices and is easily integrated with fluidics to create microvalves. Preliminary testing of the microvalve using this technology is encouraging. PDMS fluidic circuitry is being integrated with the 64 actuator system for more complex on-chip analyte manipulation. Array of such valves can be used to perform complex fluidic manipulations of picoliter volume without any outside control inputs other than an electrical connection.

ACKNOWLEDGEMENTS

Partial funding was provided by Utah State Center of Excellence grant.

REFERENCES

1. T. Thorsen *et al*, *Microfluidic Large-Scale Integration*, Science, 298, 580 (2002)
2. W. Grover *et al*, *Development and multiplexed control of latching pneumatic valves using microfluidic logical structures*, Lab Chip, 6, 623 (2006)
3. K. Shaikh *et al*, *A Modular Microfluidic Architecture for Integrated Biochemical Analysis*, PNAS, 102, 9745 (2005)
4. B. Samel *et al*, *A Thermally Responsive PDMS Composite and Its Microfluidic Applications*, JMEMS, 16, 50 (2007)
5. J. Park *et al*, *Multifunctional microvalves control by optical illumination on nanoheaters and its application in centrifugal microfluidic devices*, Lab Chip, 2007, 7, 557–564
6. D. Bartholomeusz *et al*, *Xurography: Rapid Prototyping of Microstructures Using a Cutting Plotter* JMEMS, 14, 1364 (2005)