CHIPHOLDER-INTEGRATED 3D-PRINTED PNEUMATIC LOGIC CONTROLLERS FOR MICROFLUIDIC CHIPS

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ABSTRACT

Here we design, develop and test 3D printed pneumatic controllers which can be easily built into chip holders for microfluidic devices. On-chip pneumatic controllers are used for microfluidic process automation to reduce the complexity of chip interfacing and off-chip control.[1] Commonly, on-chip elastomeric valves are used [2] but these cost chip real-estate, and often require special lithographic techniques and multilayer device design [2,3]. 3D-printed valves are a recent development.[5] We present an improved fabrication technique for 3D-printed valves and use them to construct logic control platforms which can be used on any chip with the correct fittings.

KEYWORDS: Microfluidic Logic, 3D printing, Valves

MATERIALS AND METHODS

Our pneumatic valves have a similar construction to the common PDMS valves (Fig1left) where passage of a fluid through a channel is modulated by inflating an elastomeric membrane as opposed to the stiff membranes used in [5]. Applying pressure to a control channel on one side of the membrane causes a channel on the other side to collapse. In our design, PDMS channels are replaced by 3D printed channels and the membrane is replaced by a silicone gasket. (Fig1right)

We use a FormLabs Form2 SLA Printer to fabricate our chip holders and example devices. The resin used is a proprietary blend of methacrylate monomers and polymers. The devices consist of two 3D printed blocks separated by a 0.2 mm silicone gasket. Each valve involves features on both sides of the gasket. (Fig1right) In the demonstrator device shown here, all 3D printed channels are 500 µm in diameter and the valves have a 2 mm footprint.

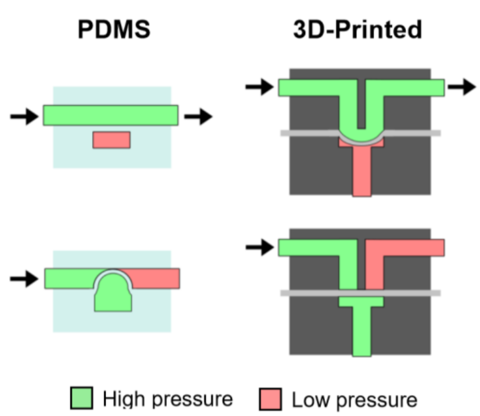

Figure 1: *(left) schematic of a classical PDMS pneumatic control valve and (right) a schematic of our printed valves. In both cases a low pressure at the "control" input allows flow through the "through" side of the valve (top) while a high pressure at the "control" side of the valve (bottom) restricts flow though the "through" side. Green indicates a pressurized channel while red features are channels at ambient pressure. Arrows indicate flow in and out of the valve. Black regions represent 3D printed material, blue is PDMS and grey is the silicone gasket.*

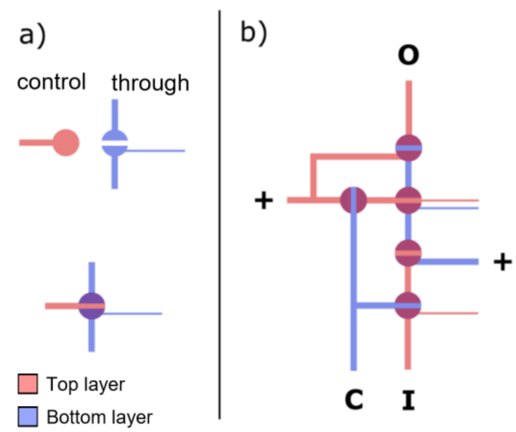

Figure 2: *(a) Schematic representation of control and through sides of a single valve, shown separately (top) and overlaid (bottom). The "control" side of a valve is shown as a solid circle while the "through" side is a split circle. Color denotes if the structure lies in the top or bottom half of the 3D printed device. Thick lines denote connections between elements and thin lines denote designed leaks to ambient pressure. (b) Schematic of a single bit of the shift register shown in Fig3. "C" denotes a link to the shared clock input, "I" denotes the link to the previous bit, "O" denotes a link to the next bit, "+" denotes a link to a shared high pressure source.*

RESULTS AND DISCUSSION

To demonstrate the efficacy of our valves we used them to implement a simple de-multiplexer integrated into a chip holder for a 5-inlet flow focusing chip. The controller mimics the behavior of a typical shift register. With one input channel and one clock channel we can uniquely set the state of as many output channels as there are bits in the register.(Fig2) In this example we drive the chip with 2 bar of pressure and can modulate the gates at a maximum frequency of 20Hz.

Further reduction in the size of our valves is limited by the quality of the printer used. In our case, the minimum diameter for the printed channels before failure was 400 microns. Imposing a safety factor of 100microns, we assume that with this printer the valves have a minimum footprint greater than 1mm.

While we demonstrate the functionality of the controller here (Fig3) we are currently developing the chip interfacing.

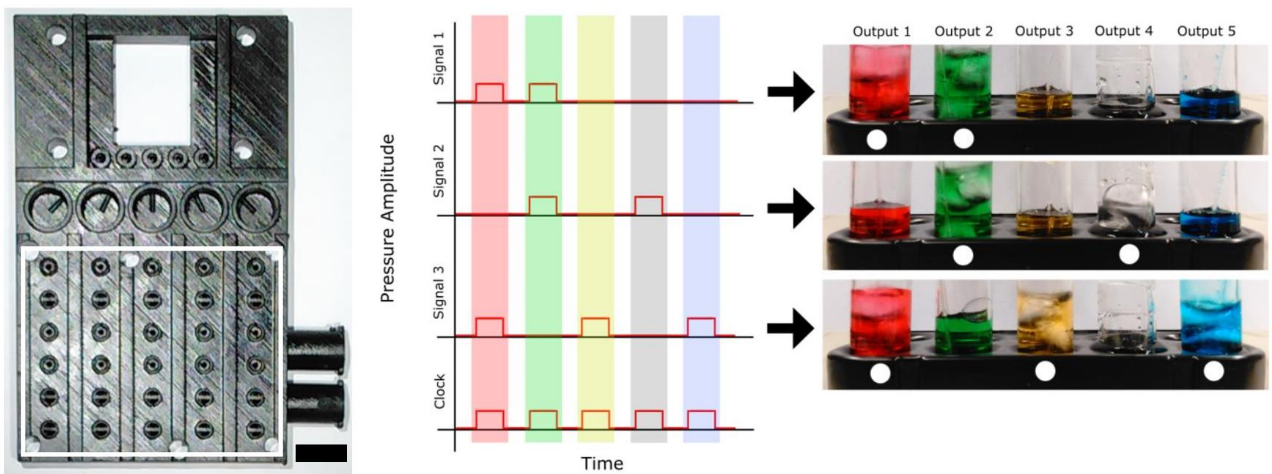

Figure 3: *Picture of one of the two 3D printed blocks that make up the shift register device (Left). In the future a chip will sit in the small window at the top of the holder and fluid in the large circular wells will be driven into the chip by pressure from the controller (outlined in white). The wells and chip interfacing are not yet functional but here we demonstrate the efficacy of the controller by routing its outputs to the vials shown in the right panel. To program the output states, clock and signal inputs are modulated as shown in the middle panel. The clock is a regular five pulse signal (middle, bottom) and is never altered. If the signal input is pressurized during a specific clock pulse a specific output is pressurized after the clock finishes cycling, else the output remains at ambient pressure. Three distinct signals and their resulting outputs are shown. Pressurized outputs are visualized by bubbling vials (right) and also marked by a white dot for clarity. Scale bar is 5 mm.*

CONCLUSION

We demonstrate a new way of fabricating pneumatic logic elements and successfully integrate them into chip holders for microfluidic devices. Our technology is easily scalable as the 3D printed pneumatic control lines are not confined to a 2D plane and fabricating stacks of printed blocks and gaskets is trivial. Furthermore, moving to a higher quality printer will help increase valve density. We hope to use our system to make modular autonomous process controllers and multiplexers as an improvement to comparable on-chip systems in the literature.[4,1]

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