Electronic Supplementary Material (ESI) for Lab on a Chip.


# Supporting Information
# High density 3D printed microfluidic valves, pumps, and multiplexers

## S1 Complete 3D printed valve CAD design

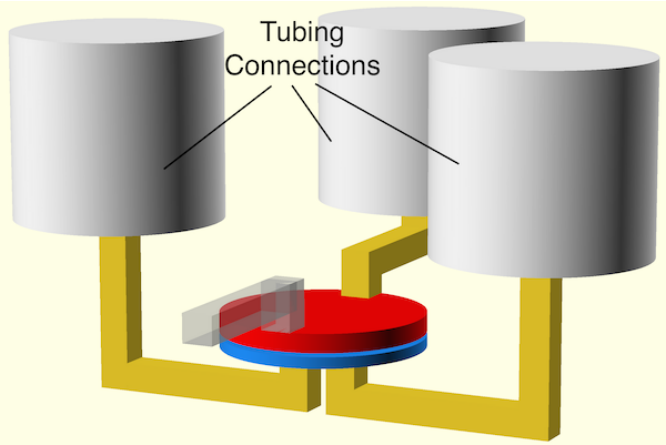


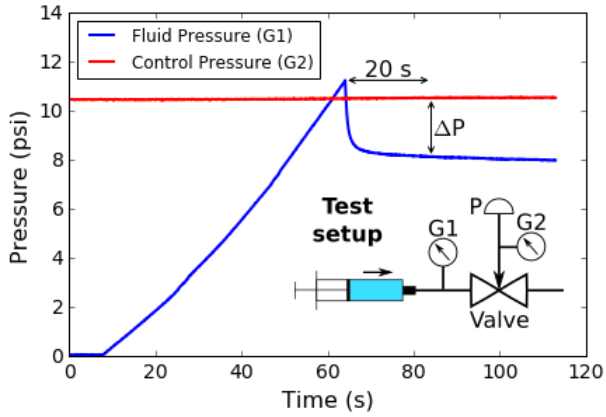

Figure S1: Complete 3D printed valve CAD design includes cylindrical holes in which to connect PTFE tubing.

## S2 Valve Performance

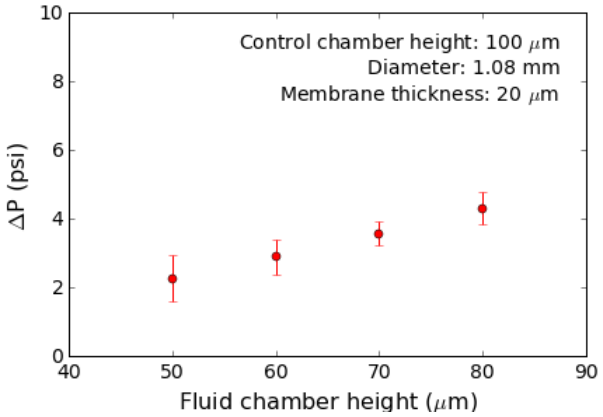
To evaluate valve performance we measured the maximum fluid pressure, $P_{fluid}$, at which the valve stays closed for a given control pressure, $P_{control}$, applied to the membrane to close the valve. A schematic of the test setup is shown in the inset of Fig. S2a. The valve fluid inlet is connected to a syringe pump, the control chamber is pressurized to deflect the membrane and close the valve, and the syringe pump is set to inject deionized (DI) water into the valve at 20 $\mu$L/min. Two pressure sensors, G1 and G2, (Honeywell 24CFFA6G) are used to continuously measure the fluid and control pressure, respectively. Fig. S2a shows the result of a typical valve pressure measurement. The fluid pressure initially rises monotonically, peaks, and then drops to a steady state which is lower than the control pressure. The pressure difference, $\Delta P = P_{control} - P_{fluid}$, is measured as the average pressure difference over a 2 second interval centered at 20 seconds after the peak fluid pressure occurs.

Figures S2b and S2c are discussed in the text.

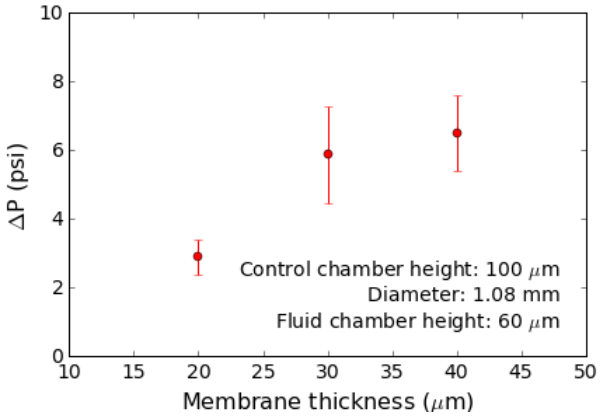
Figure S3 indicates that the post-print baking time does not affect valve performance in that the fluid pressure generated by the pump appears to be independent of baking time.




(a)




(b)




(c)

Figure S2: (a) Typical valve pressure measurement and (inset) schematic illustration of test setup. The fluid and control pressures are measured with pressure sensors G1 and G2. (b) $\Delta$P as a function of fluid chamber height and (c) membrane thickness. Each data point in (b) and (c) consists of an average of at least 10 valves, with most being an average of over 20 valves. Error bars indicate $\pm 1$ standard deviation.

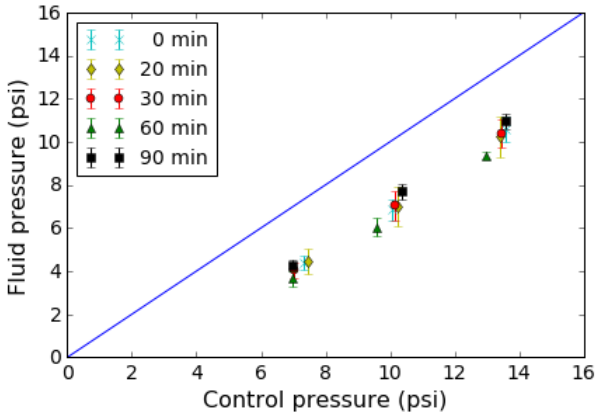



Figure S3: Valve maximum fluid pressure as a function of control pressure for different baking times. The number of valves tested for each baking time are 0 min: 3, 20 min: 8, 30 min: 9, 60 min: 8, 90 min: 7.

## S3 Pump back pressure measurement

The inset in Fig. S4 shows the experimental setup we used to measure the maximum back pressure of a 3D printed pump. The pump operates to push fluid into a closed channel in which the pressure is monitored with pressure sensor G1. The control pressure actuating the valves and DC is measured with G2. A typical measurement is shown in Fig. S4. The back pressure is calculated by averaging data in the last 10 s.

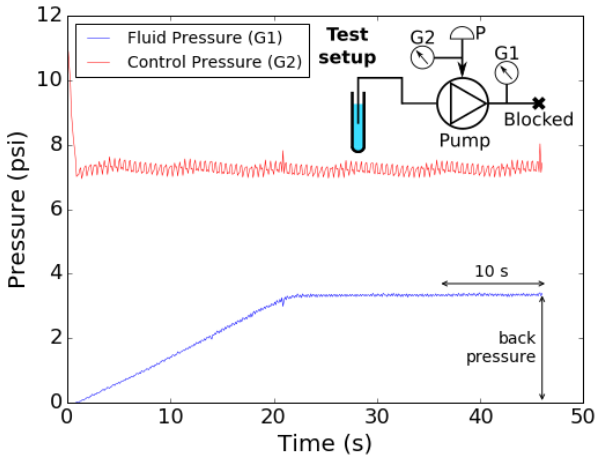



Figure S4: Typical maximum back pressure measurement and (inset) experimental setup.

## S4 Multiplexer movie

ESI Movie S1 shows the operation of a 3-to-2 multiplexer with integrated pump. During each stage of operation, the active components are labeled and arrows indicate flow direction.