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

Supplementary Information for "3D-Printed Quake-Style Microvalves and Micropumps"

3D-printing designs

3D-printed design files are imported from the CAD design program (e.g. Inventor) into Composer, which is the accompanying 3D-printing program in the Asiga printer. Some settings such as layer thickness, exposure time for each layer, burn-in layer exposure time, build plate moving speed and waiting time after exposure can be adjusted in the program. In the process of checking files in Composer, we find out that it is important to scrutinize the shape of each layer, in this case the most important layers would be the corresponding to the valve seat. There are two reasons for checking the geometry of each layer. Firstly, all structures should be placed on the zero position, i.e. the bottom layer needs to show up on the first slice. Secondly, design files are required to be converted to a different file type (.stl file) for the printer to read and print. When the Inventor design file is imported into Composer, the design is sliced (rather than appearing as a continuous structure as in Inventor); these slices are used to fabricate the prints layer-by-layer by the Asiga printer. Sometimes the 3D structure of the design may not be faithfully replicated in the print, as the layer-by-layer process can miss fine structures. Thus, checking the layers that are generated by Composer can help verify the final printed structure of 3D prints prior to printing.

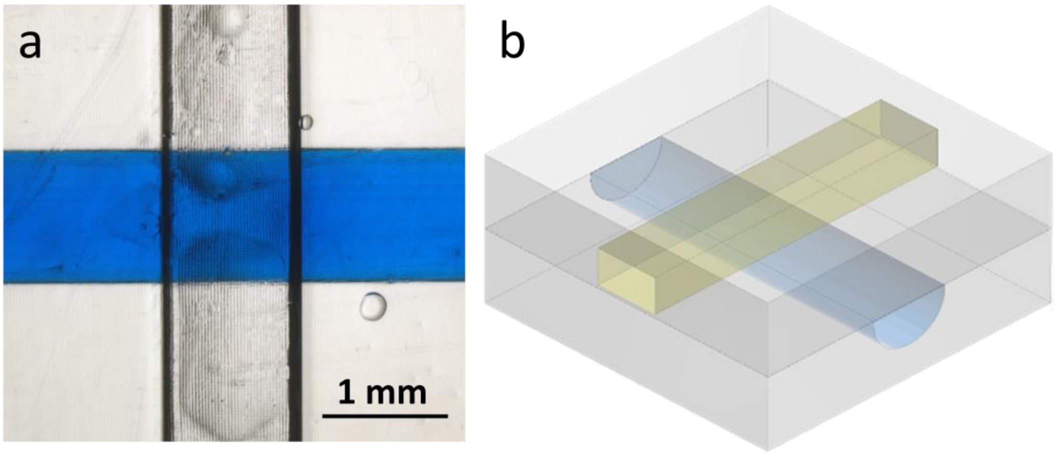
Movie S1

3D-printable Quake-style microvalve actuation. A valve filled with blue dye in the flow channel is being opened and closed repeatedly with 1 Hz, 2.5 Hz, 5 Hz, 7.5 Hz, and 10 Hz valve actuation frequencies. The valve is closed with 5 psi applied pressure and no negative pressure is applied to reopen the valve.

Movie S2

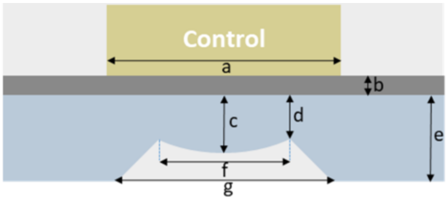
3D-printable Quake-style micropump operation. The pump is actuated with 5 different open and closed states for each valve. The flow rates are 2.22 µL/min, 7.00 µL/min, and 11.67 µL/min when the pump actuation frequencies are 5 Hz, 15 Hz, and 20 Hz respectively. The control channels are applied with +7 psi to close the valves and no negative pressures are applied to reopen the valve. The flow rates are measured by recording the liquid moving distance and the corresponding time that the movement takes in the flow channel. The video is sped up two times.

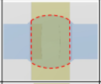
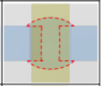
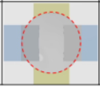
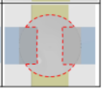
Figure S1



A valve printed with the same design as the original Quake-style valve (see Fig. 1a). (a) The pressure applied to the control channel is 11 psi, and the deflection of the membrane is barely noticeable. With this design we were not able to close the valve upon application of air pressure in the control channel. Note that the curvature, which is the rounded bottom of the flow channel, is facing up in this device. (b) The isometric view of the 3D-printed original Quake-style.

Figure S2



	Z-layer thickness	a	b	c	d	e	f	g	Membrane shape	Valve seat shape
Valves with 1.2 mm size	25 µm	1.2 mm	25 µm	100 µm	40 µm	700 µm	300 µm	1 mm		
Valves with 0.5 mm size	10 µm	0.5 mm	10 µm	75 µm	40 µm	700 µm	200 µm	500 µm		

Critical dimensions in the 3D-printable Quake valve design (not to scale, see Fig. 1b for the isometric view), shown in the cross section of the valve seat. The table shows the dimensions of two different sizes of valves. The 1.2 mm-diam. valves are shown in Fig. 2b & Fig. 5b and the 0.5 mm-diam. valves are shown in Fig. 7. The width of the control channel is = 1.2 mm (larger valves) and 0.5 mm (smaller valves). The thickness of the membrane is b = 25 µm larger valves) and 10 µm (smaller valves). The distance between the membrane and the lowest bottom of the valve seat is c = 100 µm (larger valves) and 75 µm (smaller valves), which means the membrane's maximum deflection is ~100 µm and ~75 µm for the larger valves and the smaller valves, respectively. The shortest gap between the membrane and the highest edges of the valve seat is 40 µm for both two sizes of valves; this distance determines if the flow channel will get clogged after being printed: In the case of printing larger valves, if the gap is less than 40 µm, the residual PEG-DA-258 resin in the flow channel becomes heavily photopolymerized and is hard to remove. As for smaller valves, we decided to keep the gap same distance (40 µm) to ensure that the valve seat never gets clogged. The height of the flow channel (excluding the valve seat) for both sizes of valves is e = 700 µm. The length between the two top edges of the valve seat is f = 300 µm (larger valves) and 200 µm (smaller valves). The length between the bottom edges of the valve seat is g = 1 mm (larger valves) and 500 µm (smaller valves). Both f and g should not be greater than the width of the control channel, which is a; otherwise the valve seat part will be exposed to too much UV light when the control channels walls are being built causing the valve seat to get clogged. In the membrane shape column, the red dashed contours indicate the membrane shape of larger valves (1200 µm-diam.) and smaller valves (500 µm-diam.). In the valve seat shape column, the red dashed contours indicate the valve seat shape of larger valves (1200 µm-diam.) and smaller valves (500 µm-diam.).