3D Printed Microfluidics

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Introduction: Microfluidics (lab-on-a-chip) is a critical technology for an extremely broad range of applications including bio-research, pathogen detection, point-of-care diagnostics, tissue engineering, and multiphasic screening. We are working to revolutionize the microfluidic ecosystem by developing 3D printing to routinely create very small, densely integrated microfluidic devices. Such devices are not possible with current microfluidic fabrication techniques, which typically rely on careful alignment and bonding of a handful of individually fabricated layers, each of which has a 2D component layout. In contrast, 3D printing permits all 3 dimensions of the device volume to be fully utilized for component placement and channel routing, offering the opportunity for dense component integration and extremely small device size. Moreover, print runs <1 hour will enable fast fabrication and test cycles to dramatically speed device development. Our goal is to initiate a virtuous circle in which 3D printed microfluidics becomes a disruptive tool for bio-innovation. In this presentation we discuss our progress toward this goal in terms of developing custom photopolymerizable resins and their use to demonstrate the realization of high density microfluidic devices that incorporate integrated valves and pumps.

Materials and Methods: The critical characteristic of microfluidic devices is that they consist primarily of a series of small, interconnected (micro) voids inside a bulk material. Such voids form a variety of necessary structures that include passive components (e.g., flow channels, splitters, mixers, reaction chambers, and droplet generators) and active components such as valves and pumps. Since this requirement for small, interlinked voids is in direct contrast to standard (non-microfluidic) 3D printing applications in which external features or sparse structures are important, the vast majority of 3D printing technology development has been directed toward different goals than those required for printing microfluidic devices. We have developed a mathematical model for void formation for stereolithographic 3D printing, and have used it to guide formulation of custom low cost resins to achieve the smallest (by a factor of 20) 3D printed microfluidic void cross sections using a commercial 3D printer [1].

Results and Discussion: Based on our resin work we have demonstrated robust 3D printed valves (1,000,000 actuations) and compact pumps (see Fig. 1) with a maximum flow rate of 40 μL/min [2]. We have also demonstrated high density integrated valves and pumps in a 3-to-2 multiplexer (see Fig. 2) [2].

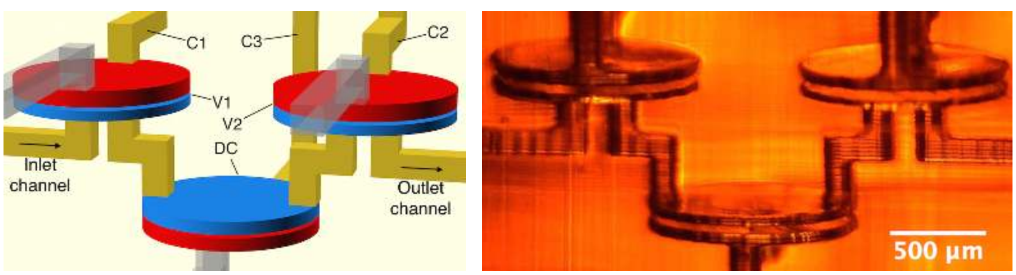

Figure 1. (left) 3D CAD layout of pump design based on 3 membrane valves. (right) Photograph of 3D printed pump using one of our low cost custom resins.

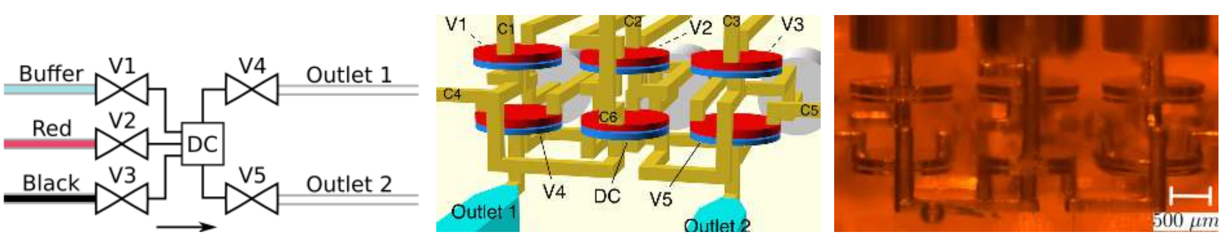

Figure 2. (left) 2D schematic design of 3-to-2 multiplexer with integrated pump. (center) 3D CAD layout. (right) Photograph of 3D printed multiplexer.

[1] Hua Gong et al., "Optical Approach to Resin Formulation for 3D Printed Microfluidics," RSC Advances, 5, pp. 105521-106632, (2015).

[2] Hua Gong, Adam T. Woolley, and Gregory P. Nordin, "High density 3D printed microfluidic valves, pumps, and multiplexers," Lab on a Chip, 16(13), pp. 2450-2458 (2016).