3D Printing Microfluidic Devices

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INTRODUCTION

MICROFLUIDICS

- Microfluidics manipulate fluids in submillimeter tunnels to allow reactions or cell growth on an extremely small scale while remaining easily observable due to clear materials.
- Microfluidic devices have become increasingly important for researching a wide variety of subjects, from cancer cells to antibiotic-resistant bacteria because of the customizable nature of the submillimeter channels. Microfluidics can also be used to create complex environments, such as with organ-on-a-chip designs, with the future potential of simulating an entire human on a chip.
- By using submillimeter channels, the effect of gravity is significantly reduced, allowing other forces to have a higher degree of control over the motion of fluids.
- Microfluidic devices also require a much smaller sample size and volume of reagents, which lowers the cost of performing experiments (6).

CONSTRAINTS OF FABRICATION

- Current fabrication of microfluidic devices involve a complex, multistep process involving soft lithography, etching and injection molding, often requiring a clean room.
- Recent developments in laser precision stereolithography (SLA) 3D printing offer broader accessibility and capabilities for microfluidic device fabrication.

The goal of this work is to assess the feasibility and limitations of microfluidic device fabrication using SLA 3D printing technology.

METHODS

MODEL

Device models were designed and created using Fusion 360 (AutoDesk,, LLC).

Two microfluidic device models were used:

- **Mixer**: Passive mixers can mix very small volumes of fluids rapidly. Laminar flow in the channels is overcome by the patterns of the channels (4).
- **Gradient:** A gradient microfluidic device often begins with two or more inputs and has channels continually branching out to facilitate the dispersal of the inputs as a gradient (5).

PRINTING

Formlabs Form 2 SLA printer with the clear resin (CL04) has the capability for 25-micron layer thickness and high optical clarity (8). The print files were generated from the STL file in Preform, where supports and orientation were modified to optimal conditions.

- Fast printing: Horizontal orientation of the device relative to the build plate.
- ***Highest quality: Vertical orientation of the device relative to the build plate.***

METHODS (continued)

POST PROCESSING

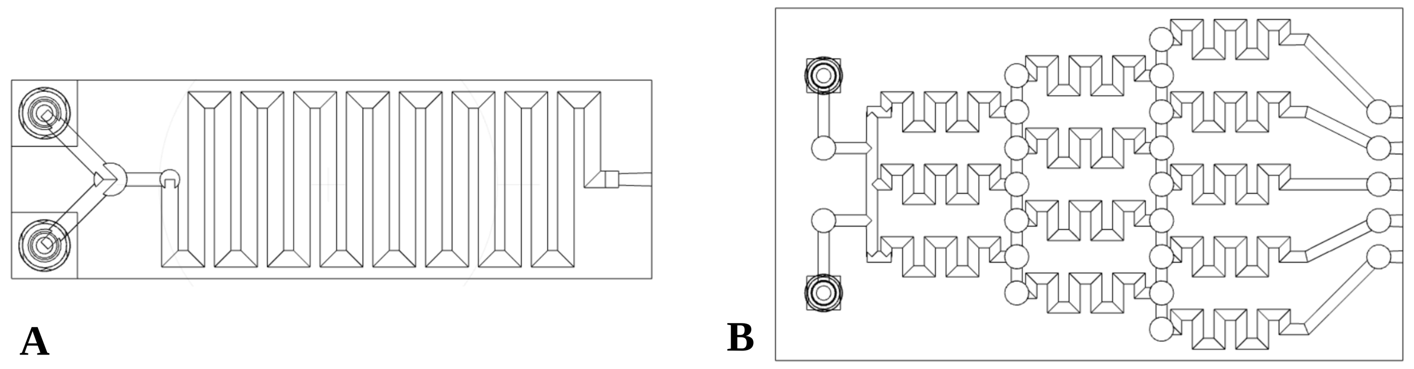
Devices are removed the build plate and initially washed with 99% isopropyl alcohol. Then, channels are then flushed repeatedly with syringes of 99% isopropyl alcohol. Finally, the entire devices remains in the Form Wash for a 10-minute cycle. Upon removal from the wash, channels are filled with water while the device is placed in the Form Cure (60 for 30 minutes).During the curing process, the device is removed (5 minute increments) and channels are flushed with water to prevent channel occlusion. The top of the device is then coated with a thin layer of clear resin and then placed into the Form Cure for 1-2 hours and then left to sit until fully dry.

QUANTIFICATION

Images under 4X magnification light microscopy are captured at multiple locations on the device. A micrometer, sitting on a 3D-printed mount to ensure the same depth as channel measurements, was used to calibrate the image data.

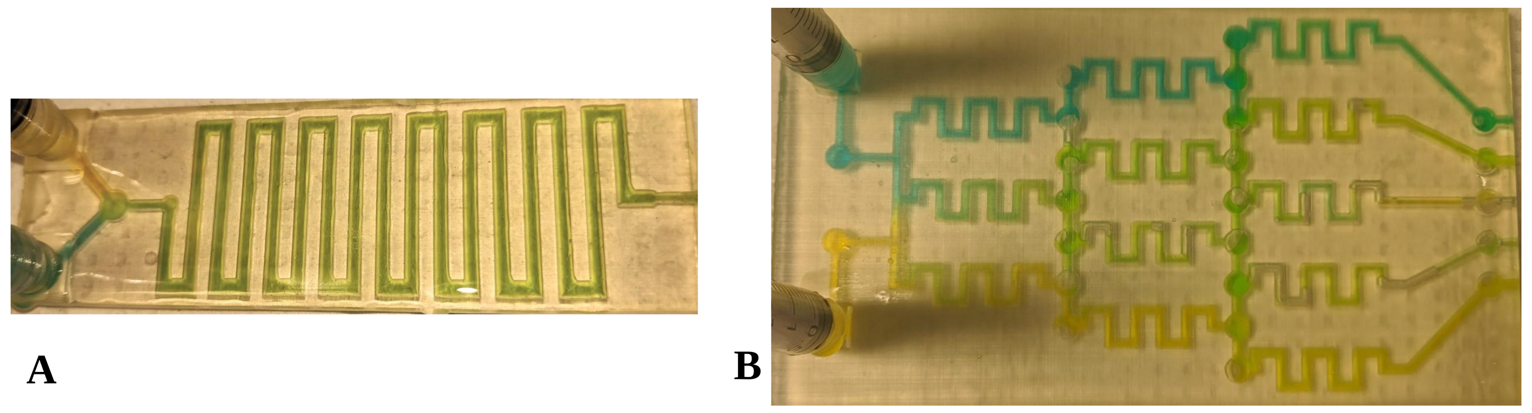
Images were then loaded into ImageJ. Thresholding to enhance channel contrast and line profiles were used to determine the dimensions of the channels. Measurements were compared to theoretical channel values.

RESULTS



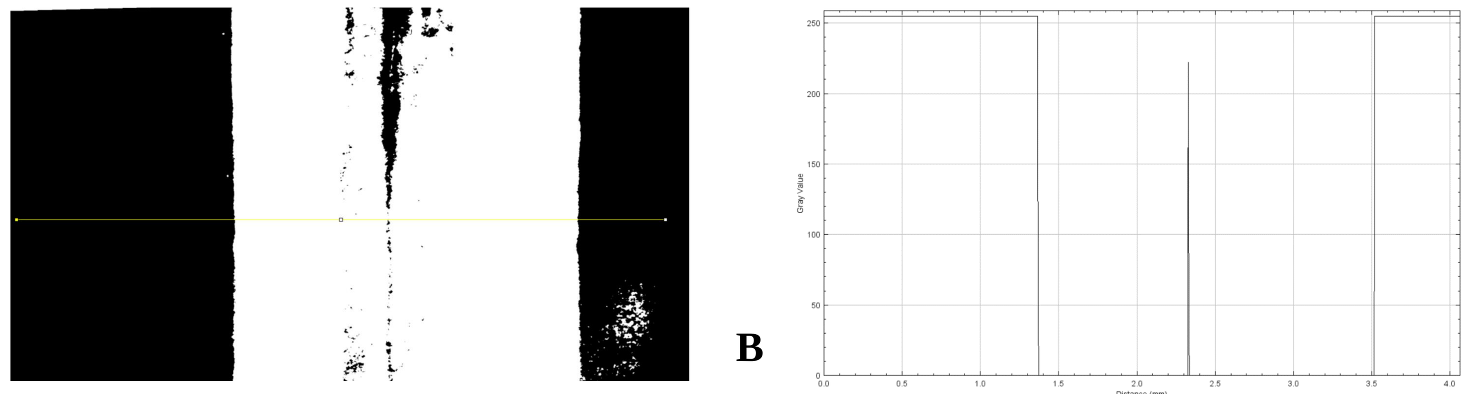
A B

Figure 1. 3D Fusion 360 models of the mixer (A) and gradient devices (B). Input ports are on the left for both devices. The mixer has one exit port while the gradient device is capable of distributing five distinct concentrations.



A B

Figure 2. Fabricated devices using SLA 3D printing technology. Initial testing involved mixing liquids dyed with different colors (blue and yellow). In panel A, the mixer produces a final green-colored solution while B shows varied concentrations of the two colors mixed.



B

Figure 3. Panel A shows a channel thresheld to contrast inner channel diameter. The line tool produced a line profile (B) which was used to more accurately take measurements of the channels..

RESULTS (continued)

Table 1. Channel Measurement Results and Statistics

Device: Mixer		Channel Location		
		Upper Quadrant *(mm)*	Middle Quadrant *(mm)*	Lower Quadrant *(mm)*
	1	2.17	2.16	2.16
	2	2.16	2.13	2.32
	3	2.18	2.18	2.20
Average		**2.17**	**2.16**	**2.23**
Std. Dev.		**0.007**	**0.026**	**0.085**
Percent Error		**13.1%**	**13.7%**	**10.9%**

DISCUSSION AND FUTURE WORK

The mixer and gradient devices were designed and fabricated using the SLA 3D printer. These models showed promising qualitative functionality.

SLA 3D printing technology can successfully produce a mixer devices with channel diameters of 2.5 mm, with less than 15% error.

Future work includes :

- Assessing the gradient device for channel precision/accuracy
- Using a colorimetric calibration curve to determine accuracy of mixing and gradient functions.

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