Complex Fluid Flows

Annabelle McGregor, *Massachusetts Bay Community College*
Barrett T. Smith, *Chemical Engineering, Northeastern University*
Dr. Sara M. Hashmi, *Chemical Engineering, Northeastern University*

Northeastern University
College of Engineering

Northeastern University
Michael B. Silevitch and Claire J. Duggan Center for STEM Education

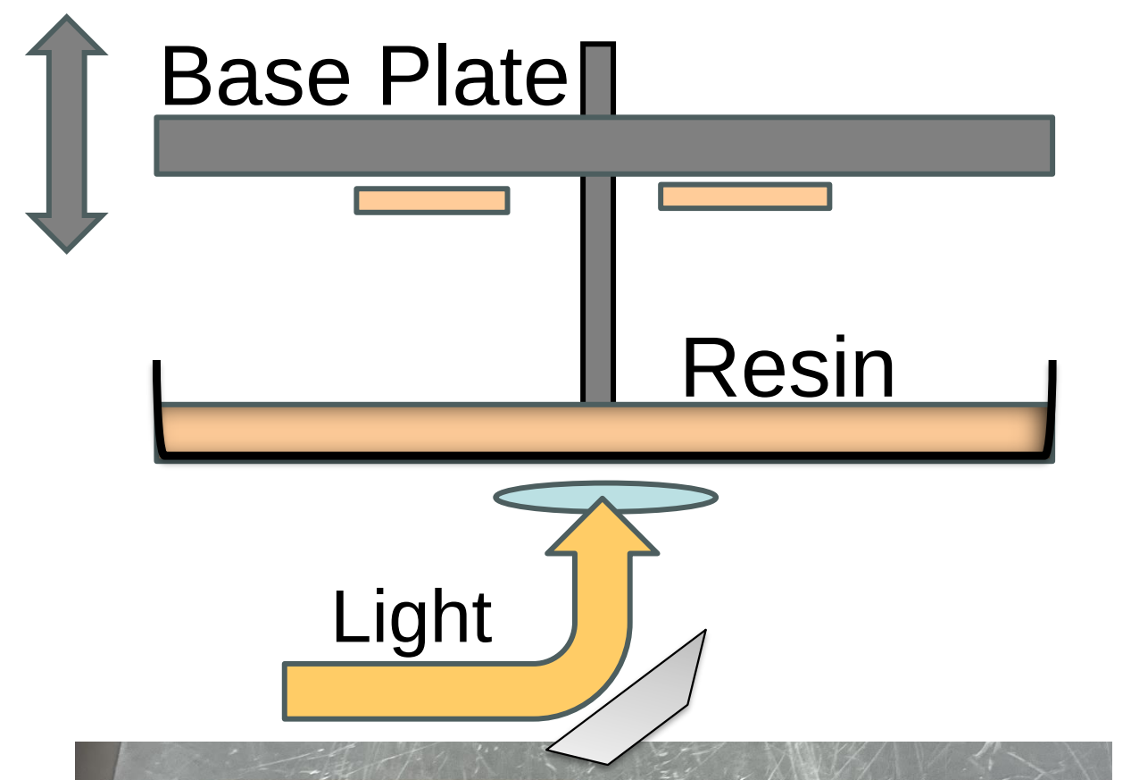
Abstract

Alginate is a biopolymer derived from seaweed which can be crosslinked by calcium ions to form a widely biocompatible hydrogel used in biomedical, cosmetic, and food industries. We recently developed a way to produce alginate hydrogel rods in a microfluidic Y-shaped device[1]. Altering the channel geometry and chemical conditions changes the length, thickness, and stiffness of the alginate rods. Previous channel geometries for making rods did not yield rods big enough to test with macroscopic methods. The traditional way to make new molds for microfluidic channels, photolithography, is slow and expensive. Our new exploration seeks to develop larger microfluidic channels using 3D printing, which is cheaper and faster than photolithography. The channels produced from the 3D printed templates are rougher than channels formed by traditional methods. By optimizing printing conditions and exploring new channel geometries, we successfully produced larger alginate rods, significantly enhancing their potential for macroscopic characterization.

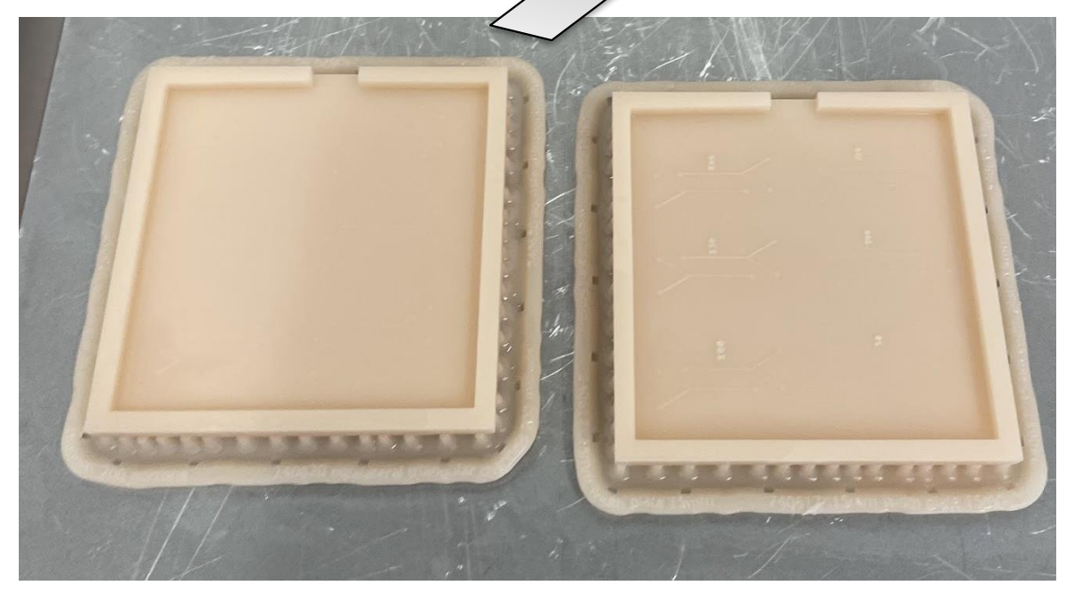
[1] Smith, Hashmi. "In situ polymer gelation in confined flow controls intermittent dynamics" ***Soft Matter***, 2024,**20**, 1858-1868

Fluidic device fabrication

Stereolithography

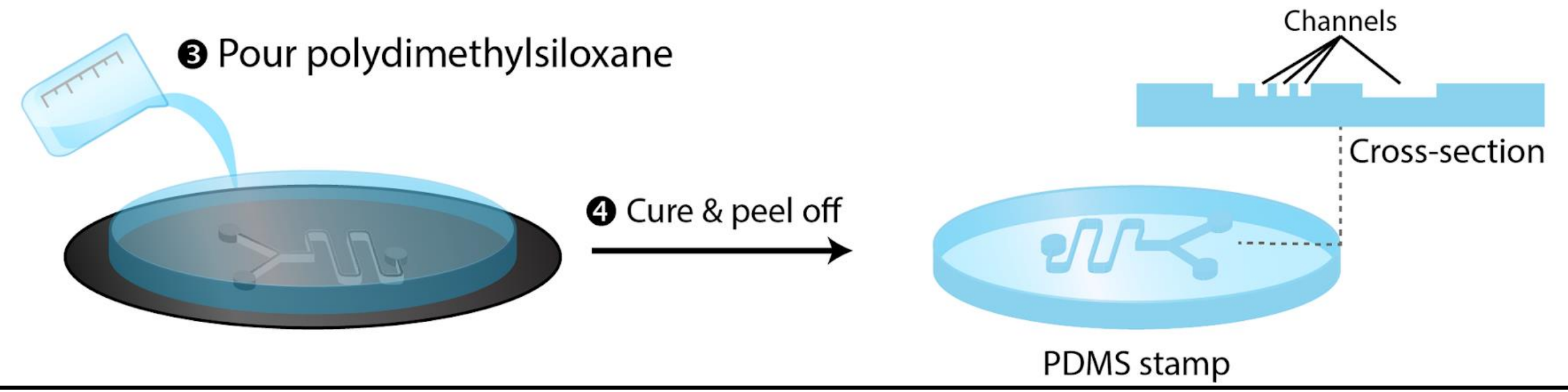


- Printed upside down
- Orientation is in respect to the base plate
- Light is focused through a lens to cure the resin
- Excess resin cleaned off with IPA before final curing step



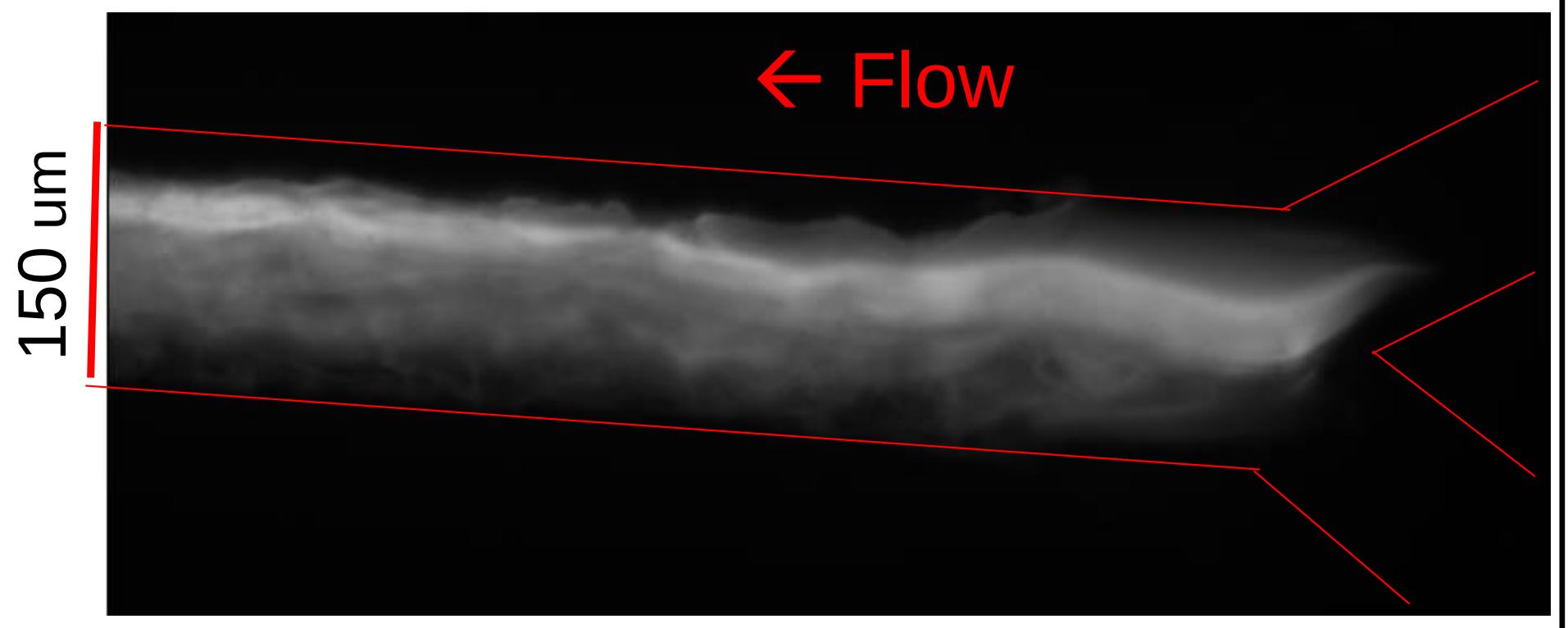
Soft-Lithography

- Polydimethylsiloxane (PDMS) poured over master mold
- Sealed to microscope slides using a plasma cleaner

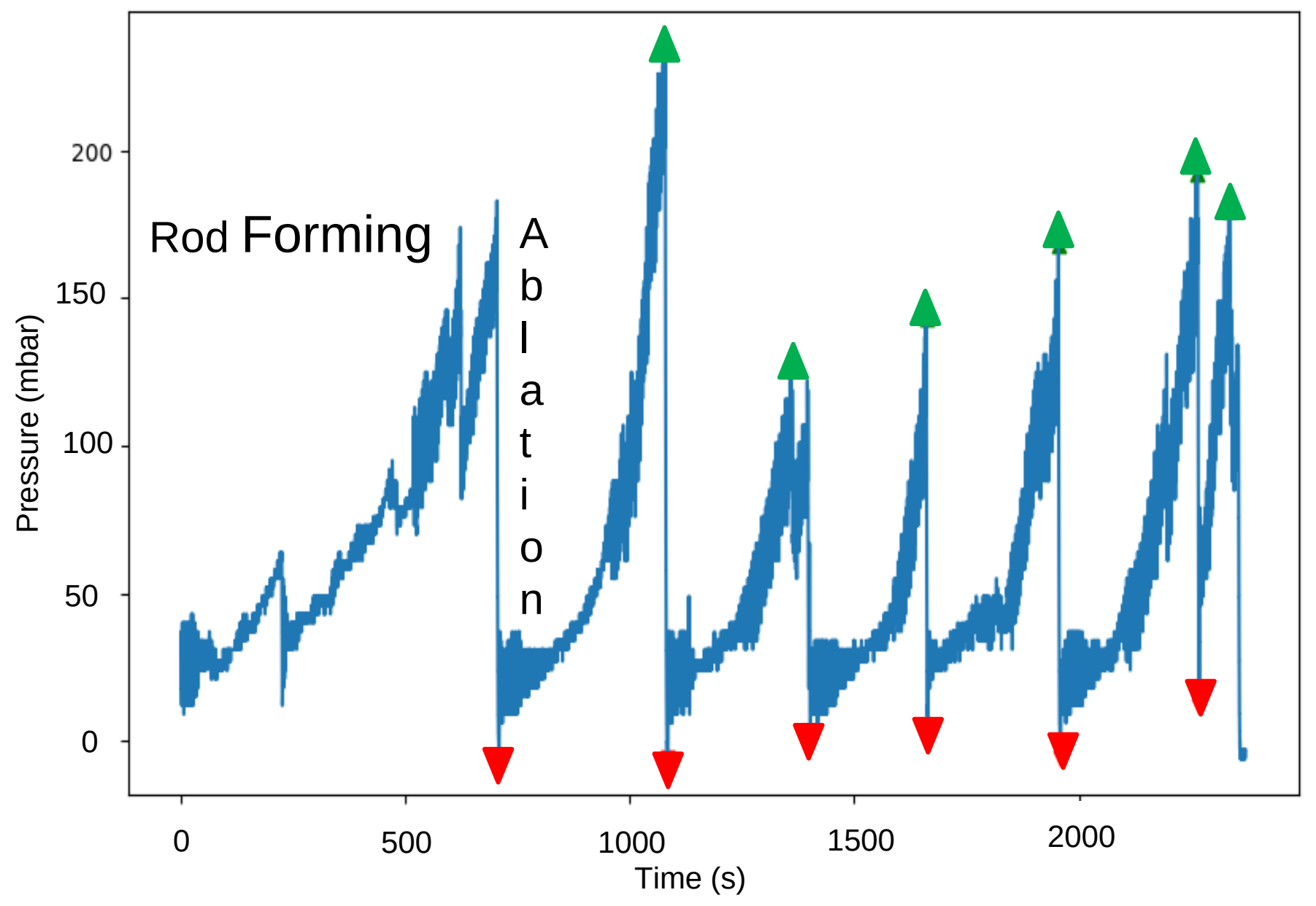


Methodology

Solutions of fluorescent alginate and calcium are run through the channels at a constant flow rate (10uL/min each). At the Y-intersection, a gel forms and deposits in the channel [Fig. 3]. The gel grows to obstruct the channel, and a higher pressure is needed to maintain the flow rates. After the gel grows to a critical size, the gel ablates from the channel walls resulting in a dramatic drop in pressure. The rod leaves the device, and their dimensions are recorded.



[Fig.3] Rod forming in a 150 um by 100 um channel



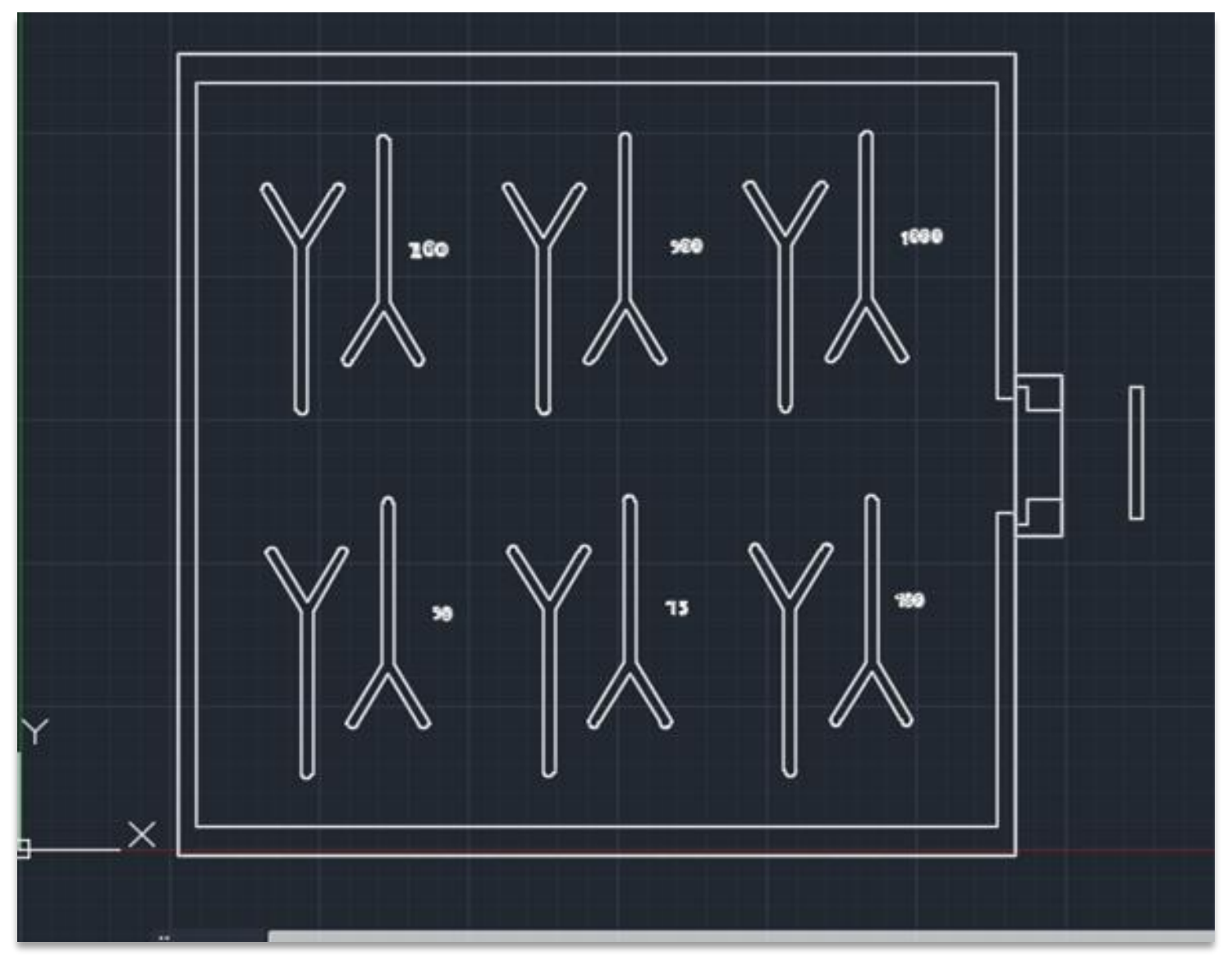
[Fig. 4] 150 um by 100 um rectangular channel
Pressure Trace Analysis

The pumps pressure is recorded and plotted. [Fig. 4]
Each peak signifies a rod being expelled from the channel.
Barrett's channels produced 60 hydrogel rods per hour.
The biggest rod reaching only 1 mm.

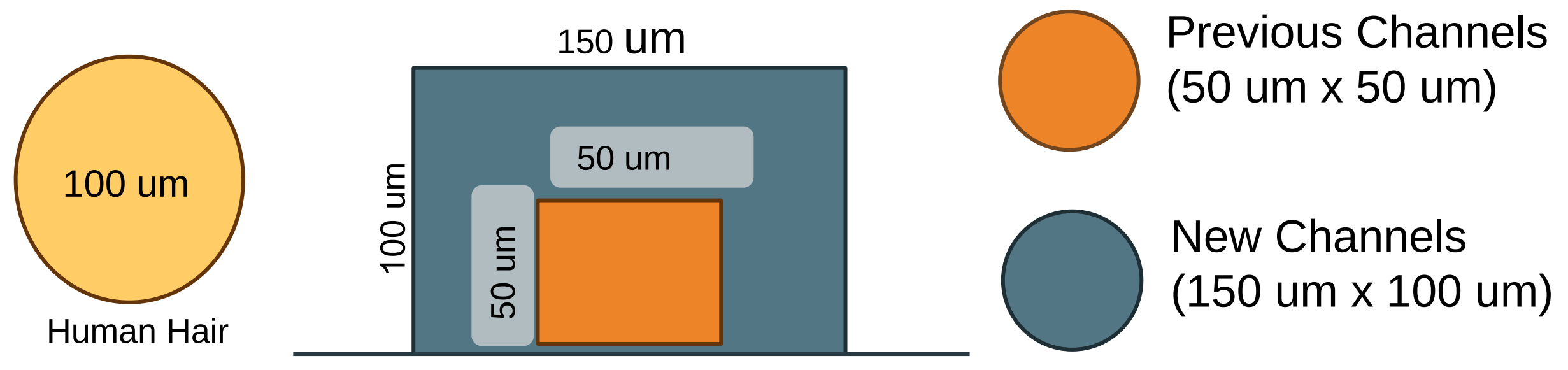
Question: Will larger channel sizes make larger rods?

Challenge: Smaller fluidic channels require cleanroom fabrication steps; these are costly and time consuming. We want to try a cheaper, easier option that will enable larger channel sizes.

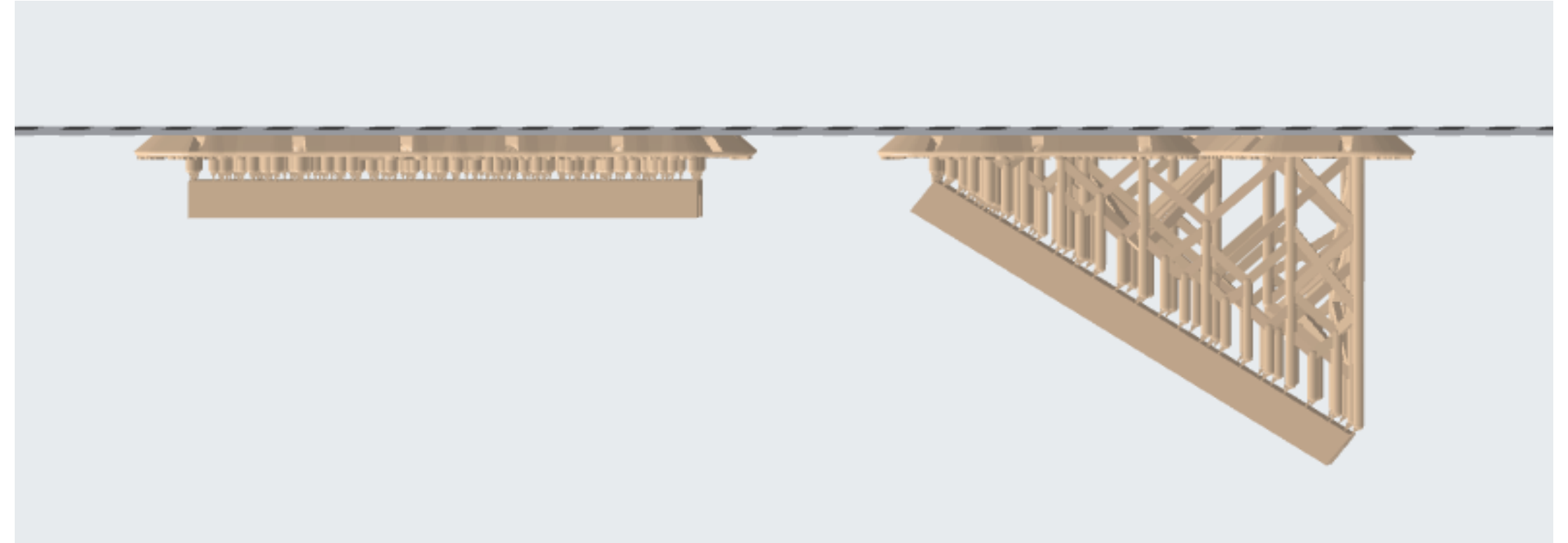
AutoCAD was used to design 3D master molds of fluidic devices with varying geometries [Fig. 5]. The template was printed using FormLabs 3L Stereolithography (SLA) 3D printers. Model and clear resin can print layers the width of 50 microns. Model was found to be the optimum resin for PDMS based microfluidic channels. The PDMS was able to cure and pull off of the molds like normal. [Fig. 6] shows my channels compared to Barrett's channels



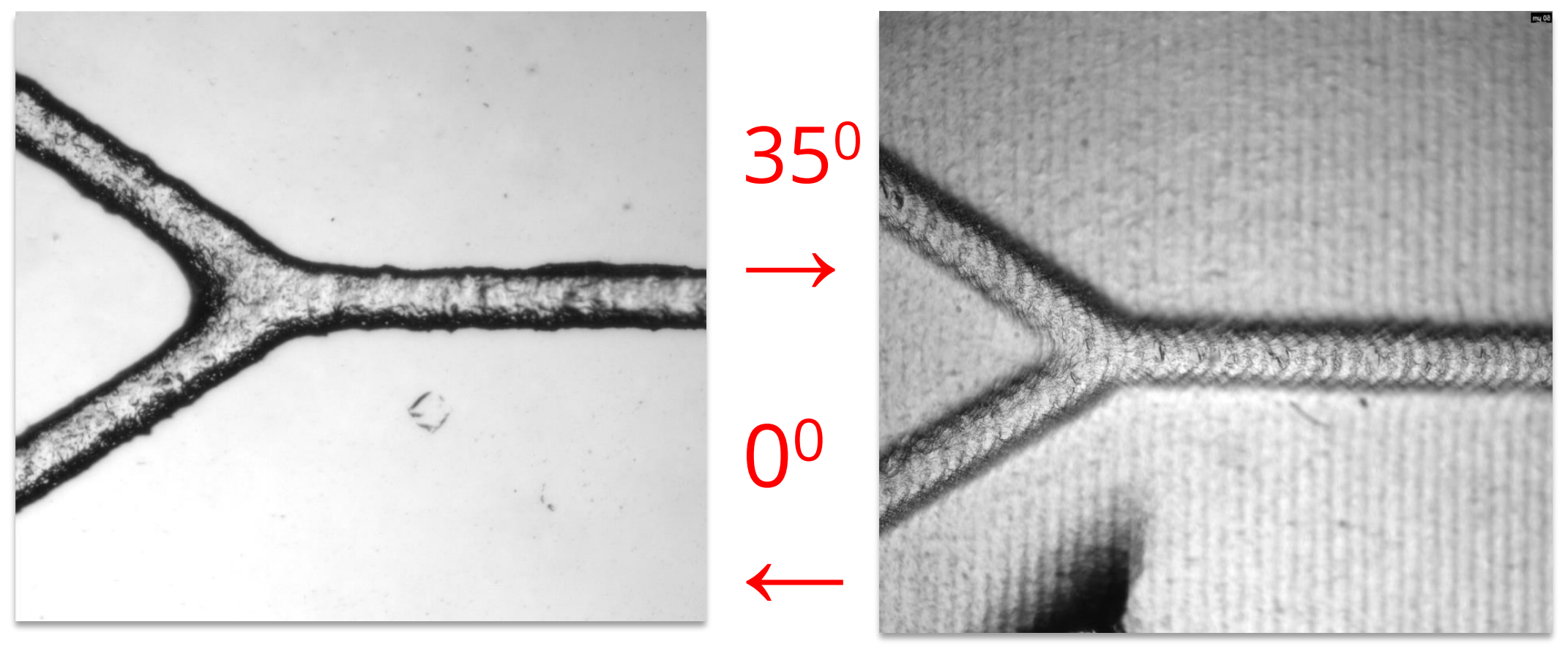
[Fig. 5] 1mm wide channel template designed in AutoCAD



[Fig. 6]



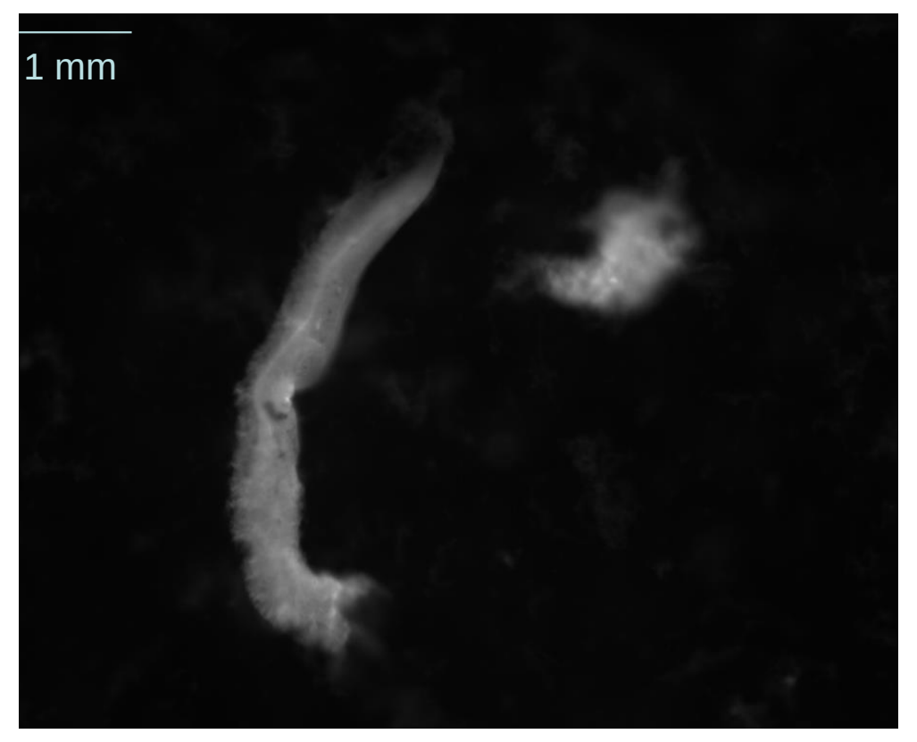
For most uses with an SLA printer it is recommended to orient your prints about 45 for more successful prints. After testing angles from 10 to 90 degrees, anything above 0^0 creates ridges from the layers. [Fig. 7] Which does not work as microfluidic devices need to seal to microscope slides so we can run flow tests through them.



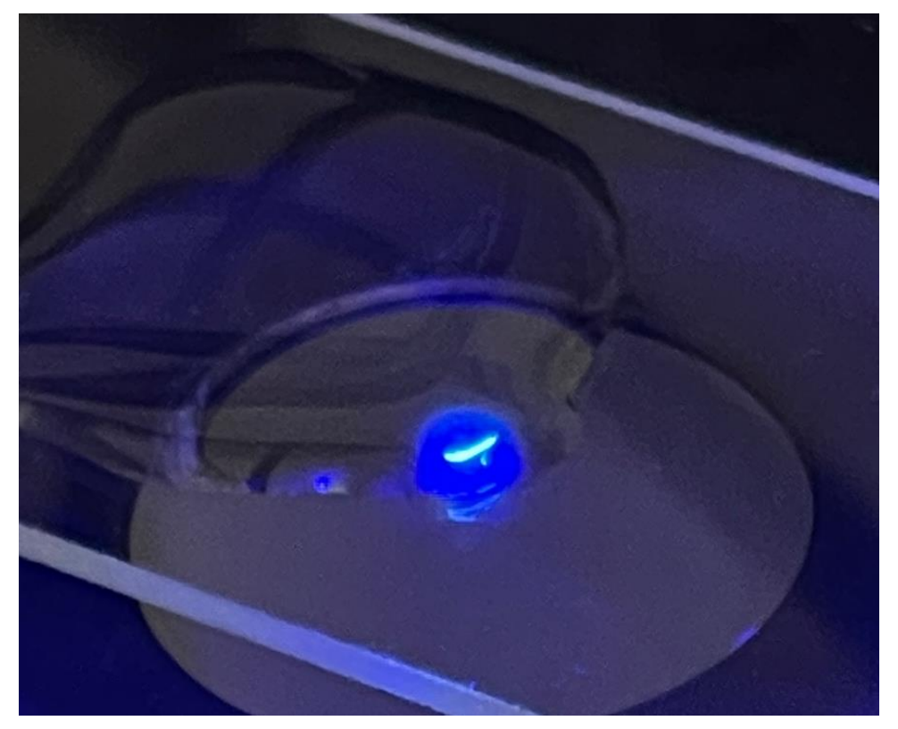
[Fig. 7]

Results

SLA printing using model resin makes usable microfluidic channels.



3.4 mm rod 4x mag from 150 um x 100 um channel



3.4 mm rod on microscope slide Phone camera

Old Channels (50 um x 50 um)	New Channels (150 um x 100 um) [Fig. 4]
60 per hour	6-7 per hour
<1 mm long	<4 mm long
2 uL/min	20 uL/min

This method of making hydrogel rods works on a larger scale, however they take longer to make

Conclusions and Future Outlook

The cost of one, reusable resin master mold comes out to \$3. The templates are easily customizable and take 1-3 hours to print. Producing alginate rods in different sized channels will allow better understanding of the relationship between channel geometry, rod formation, and the properties of the resulting hydrogels. It will be interesting to see if the rods can take on different shapes and if they can be made large enough to find

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Complex Fluids Lab
PI: Sara M. Hashmi, Chemical Engineering
northeastern.edu/hashmilab

NSF REU-Site: Research Experience for Undergraduates site to create "Pathways for Community College Students to Enrich their Education and Careers" (REU - PATHWAYS)

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