

Masked Stereolithography Microfluidic Device for Passive Cell Separation with Automated Design

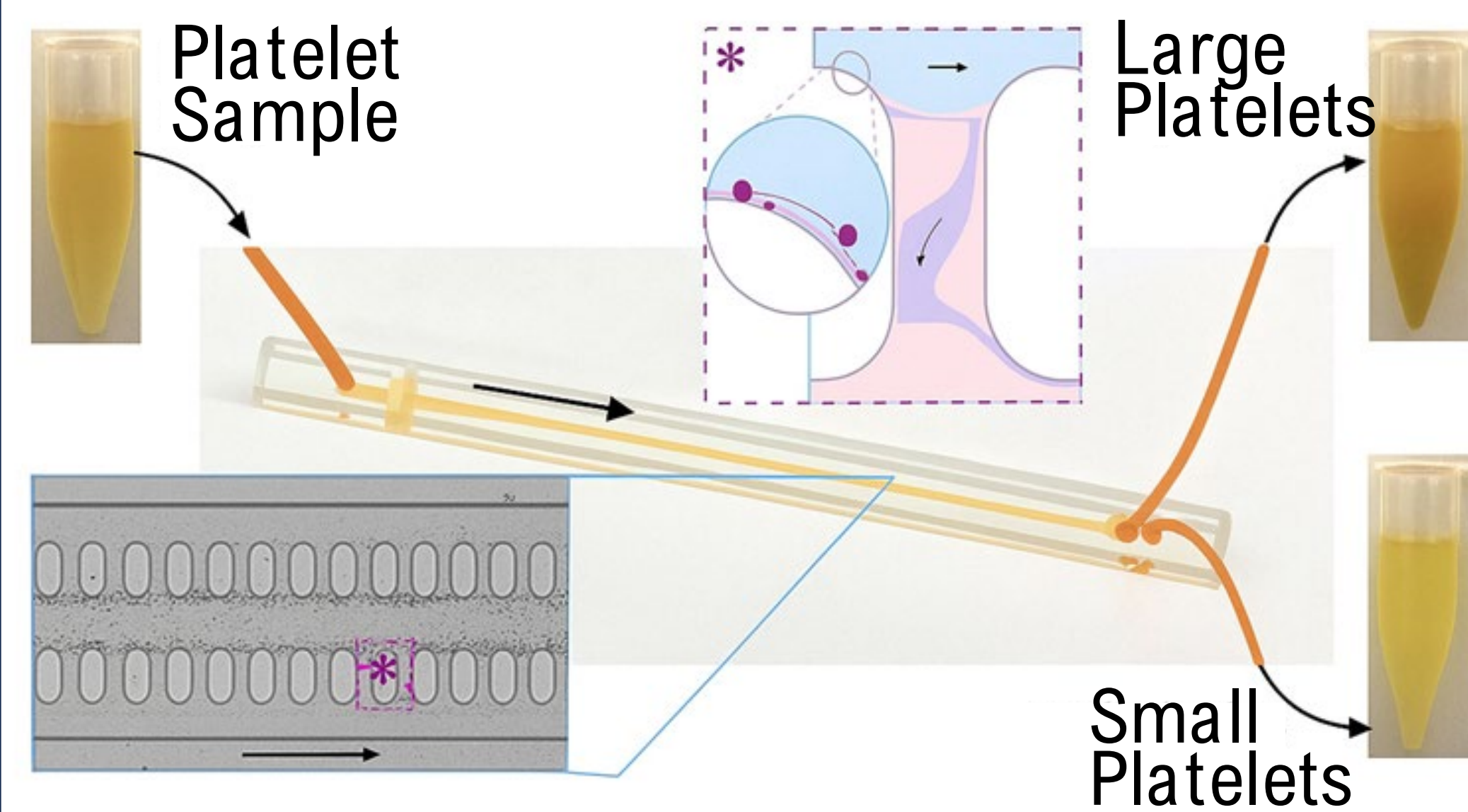
Adil Alam, Alma Gallardo Campa, Ben Morris, Luciana Aguirre, Cullen College of Engineering
Mentor: Dr. Sergey Shevkoplyas, Cullen College of Engineering

Objective

To develop an affordable microfluidic cell separation device using mSLA 3D printing and automated MATLAB design, eliminating the need for cleanroom fabrication and enabling precise, passive size-based cell sorting in resource-limited research and clinical settings.

Background

- Cell separation by centrifugation is limited by large sample volumes and cell damage risk.
- Current microfluidic devices offer >95% separation efficiency but need for cleanroom keeps them inaccessible to most labs.
- This project uses a consumer-grade mSLA 3D printer and automated MATLAB design tool to bring microfluidic cell separation to resource-limited settings at \$1 based on resin cost.



Methods

- Devices were fabricated using masked stereolithography (mSLA) 3D printing.
- Iterative process of designing channel geometries was done using Fusion.
- Devices were printed on a consumer-grade Elegoo Mars 5 Ultra and post-processed with IPA washing and UV curing.
- COMSOL Multiphysics simulations were run in parallel to model fluid flow.
- Performance was then validated by flowing small particles through the device.

CAD Design

Reynolds Number:
Predicts flow behavior, laminar flow ($Re < 100$).
Using water properties ($\rho \approx 1000 \text{ kg/m}^3$, $\mu \approx 0.001 \text{ Pa}\cdot\text{s}$), Reynolds number simplifies to:

$$Re = v \cdot D_h$$

Channel 1: $0.6 \times 0.6 \text{ mm}$
 $Re = (1.39)(0.6) = 0.83$

Channel 2: $0.3 \times 0.6 \text{ mm}$
 $Re = (2.78)(0.4) = 1.11$

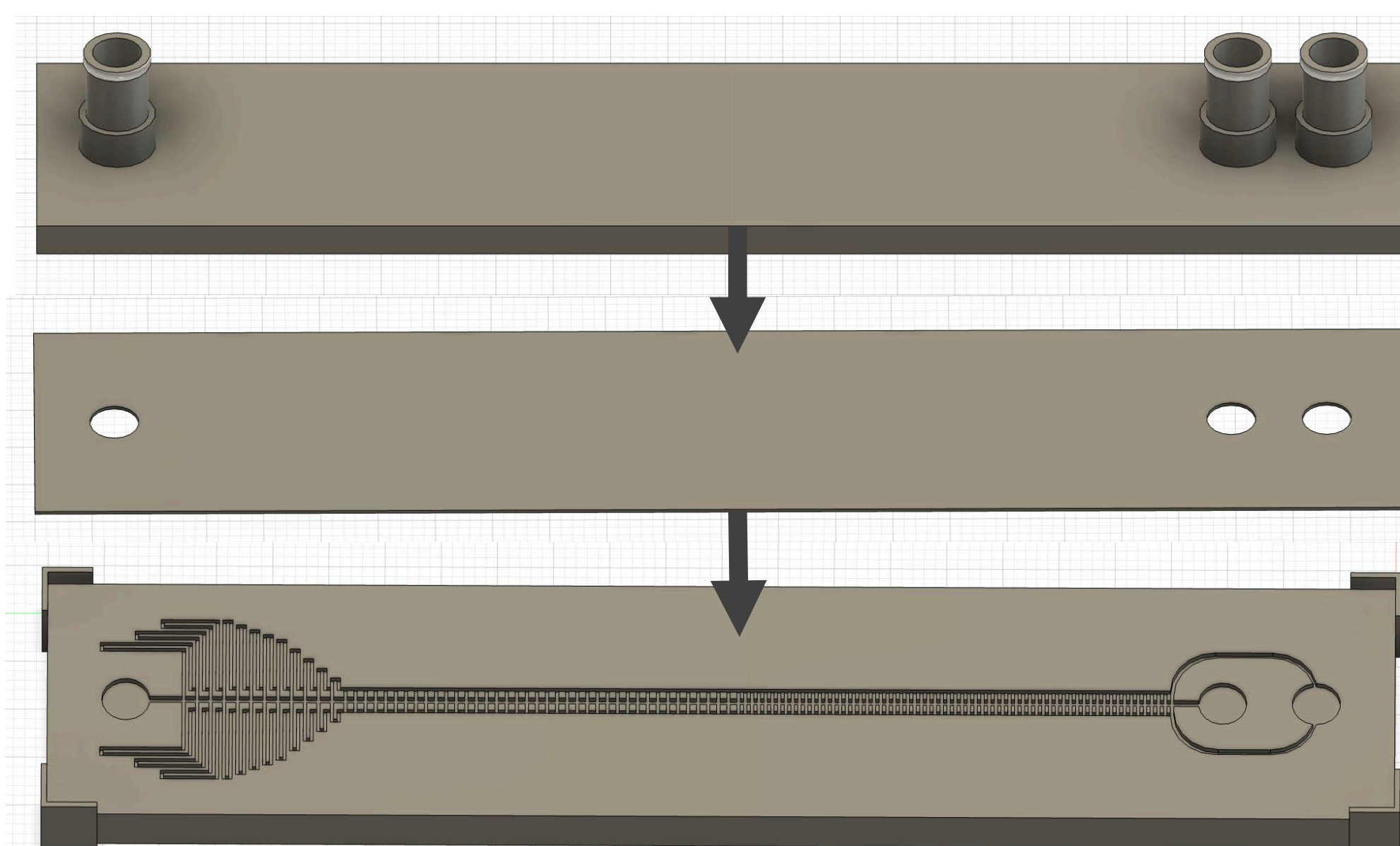
Smallest gap: $0.1 \times 0.6 \text{ mm}$
 $Re = (8.33)(0.171) = 1.42$

Hydraulic Resistance:
Fluid distribution through different pathways

$$R_h \propto \frac{L}{wh^3}$$

Channel 1: $0.6 \times 0.6 \text{ mm}$
 $L = 95 \text{ mm}$ $R_h = 2.38 \times 10^{10} \text{ Pa} \cdot \text{s}/\text{m}^3$

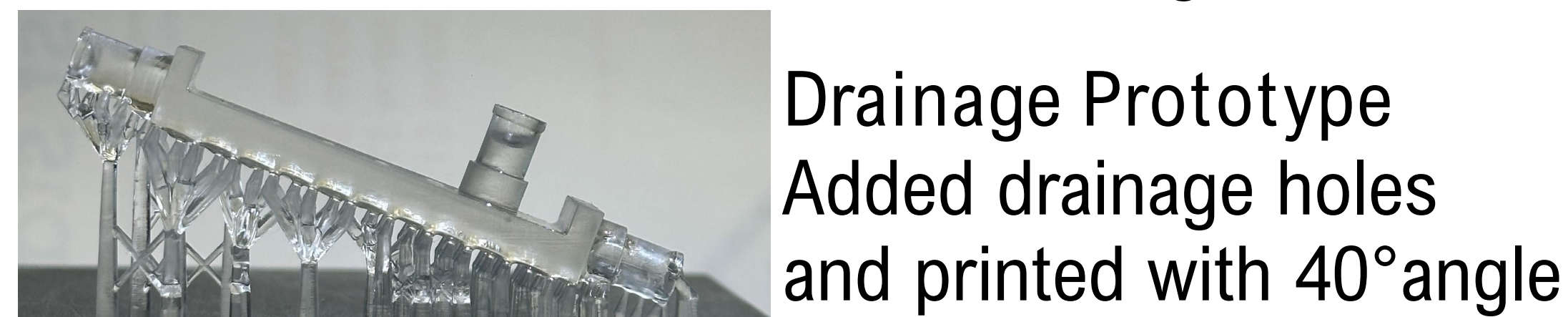
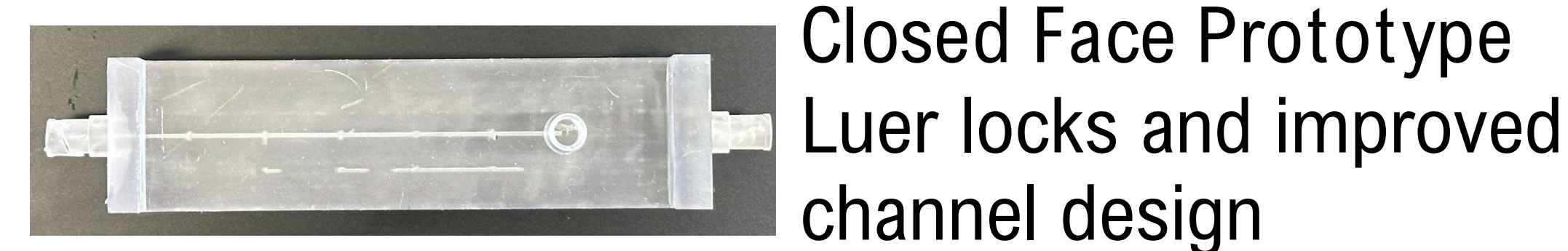
Channel 2: $0.3 \times 0.6 \text{ mm}$
 $L = 13.20 \text{ mm}$ $R_h = 1.43 \times 10^{10} \text{ Pa} \cdot \text{s}/\text{m}^3$
 $L = 6 \text{ mm}$ $R_h = 6.49 \times 10^9 \text{ Pa} \cdot \text{s}/\text{m}^3$
 $L = 3 \text{ mm}$ $R_h = 3.24 \times 10^9 \text{ Pa} \cdot \text{s}/\text{m}^3$
 $L = 1 \text{ mm}$ $R_h = 1.08 \times 10^9 \text{ Pa} \cdot \text{s}/\text{m}^3$



Results

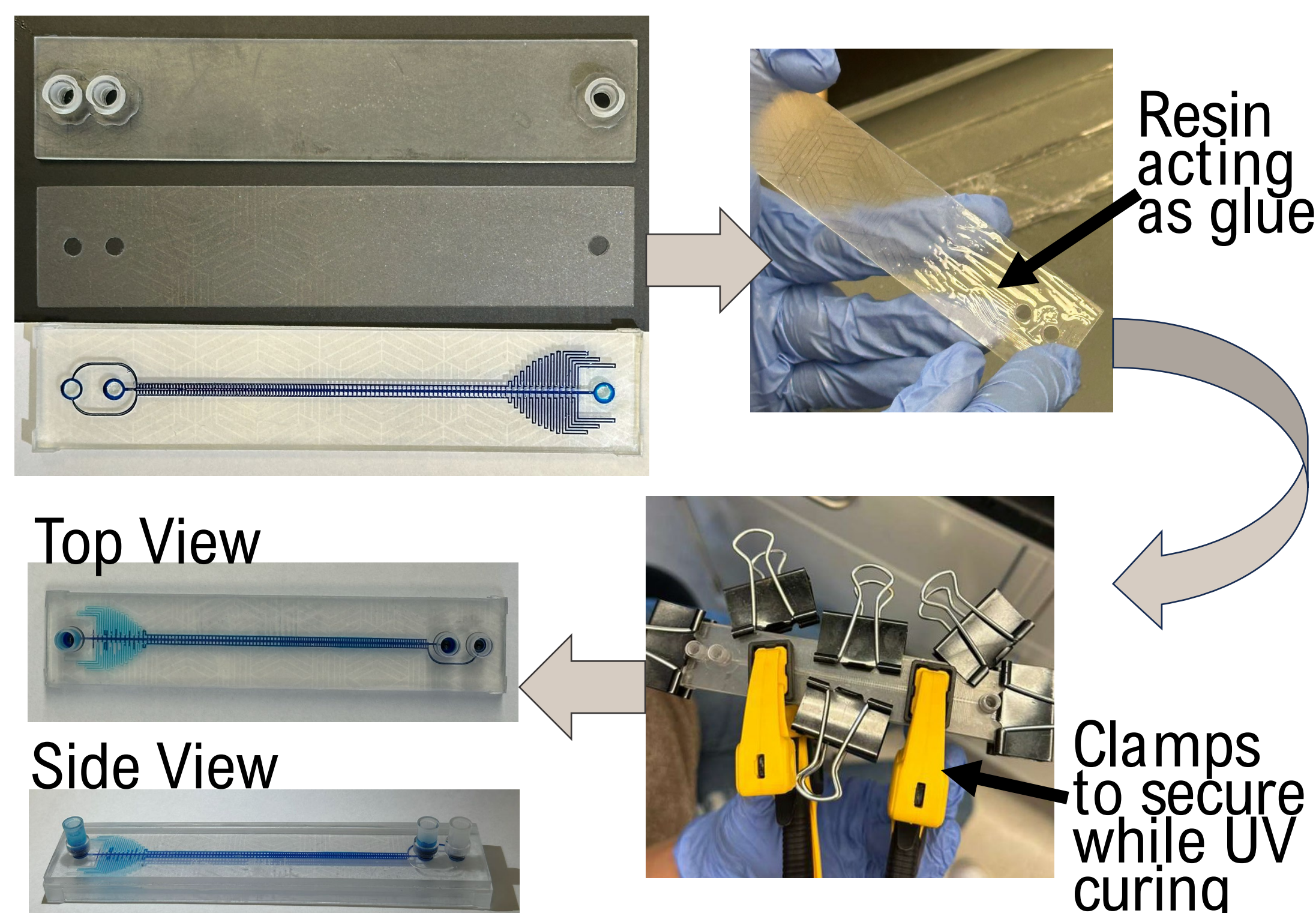
Printing

Device geometry was refined through 10+ iterations to maximize resolution and prevent resin-induced clogging. Key prototypes explored:



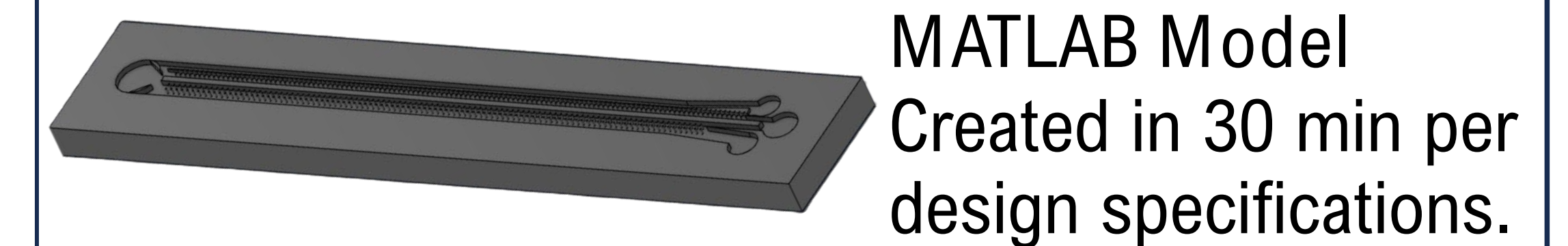
Final Design: 3-Piece Device

- Channels down to 0.1 mm printed
- 3-piece design prevents clogged channels
- Bonded sealing using resin to ensure no leaks

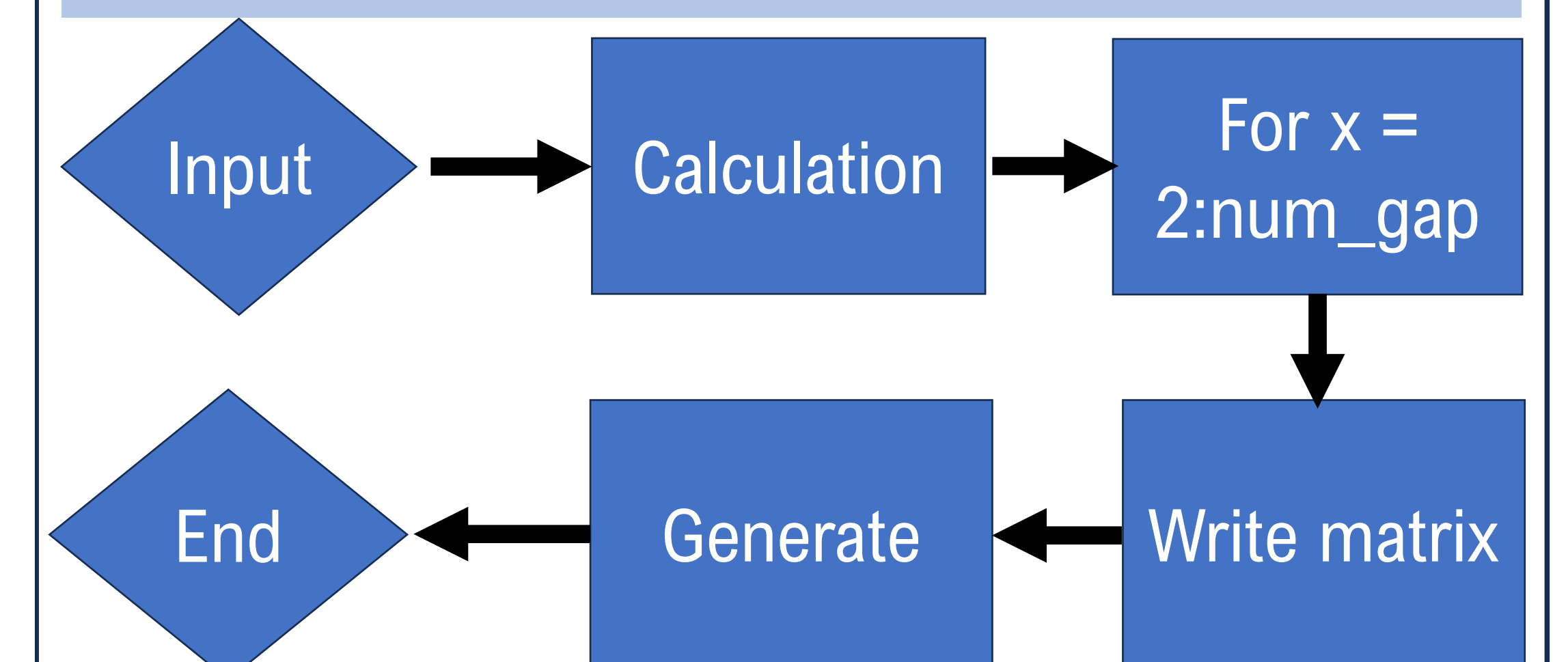


Software

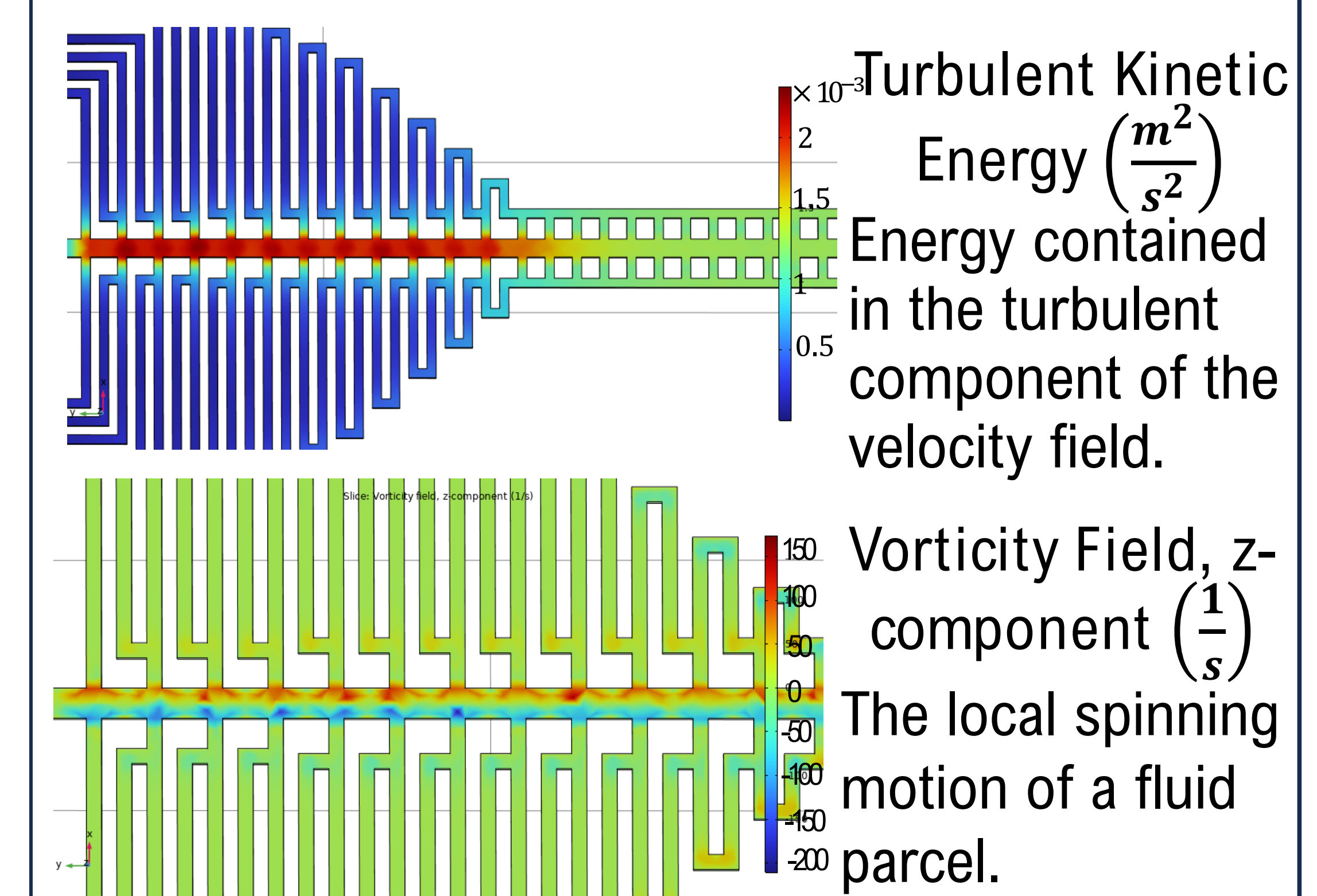
MATLAB code created 2D coordinate sketch which decreases limitations on design, lowers amount of time it takes to create a device, and increases customizability of the product.



Pseudocode Flowchart



COMSOL Simulation



Conclusion

Cleanroom-dependent fabrication has kept microfluidic cell separation inaccessible for most labs. This project addressed that barrier by developing a fully consumer-grade mSLA fabrication workflow capable of producing functional separation devices for \$1 each, based on resin used per device. A 3-piece open-face design resolved resin bleed-through, and a MATLAB automation pipeline was built to generate print-ready STL files from user inputs. The broader significance lies in health equity, bringing cell separation to resource-limited clinics. Next steps include quantification and validation of microbead separation, and progression toward whole blood testing.

Acknowledgments

We would like to acknowledge our mentor Dr. Sergey Shevkoplyas and our Capstone advisor Dr. Yuncheng Du. Many thanks to them for guiding us during our project.