Design of a Transparent Digital Microfluidics Platform

Megan Chisling, Jaedyn Foley, Laura Lavallee, and Cameron Polglase
Group 21, Supervisor: Dr. Karolina Valente, July 30, 2021
University of Victoria, Department of Biomedical Engineering

Background Information

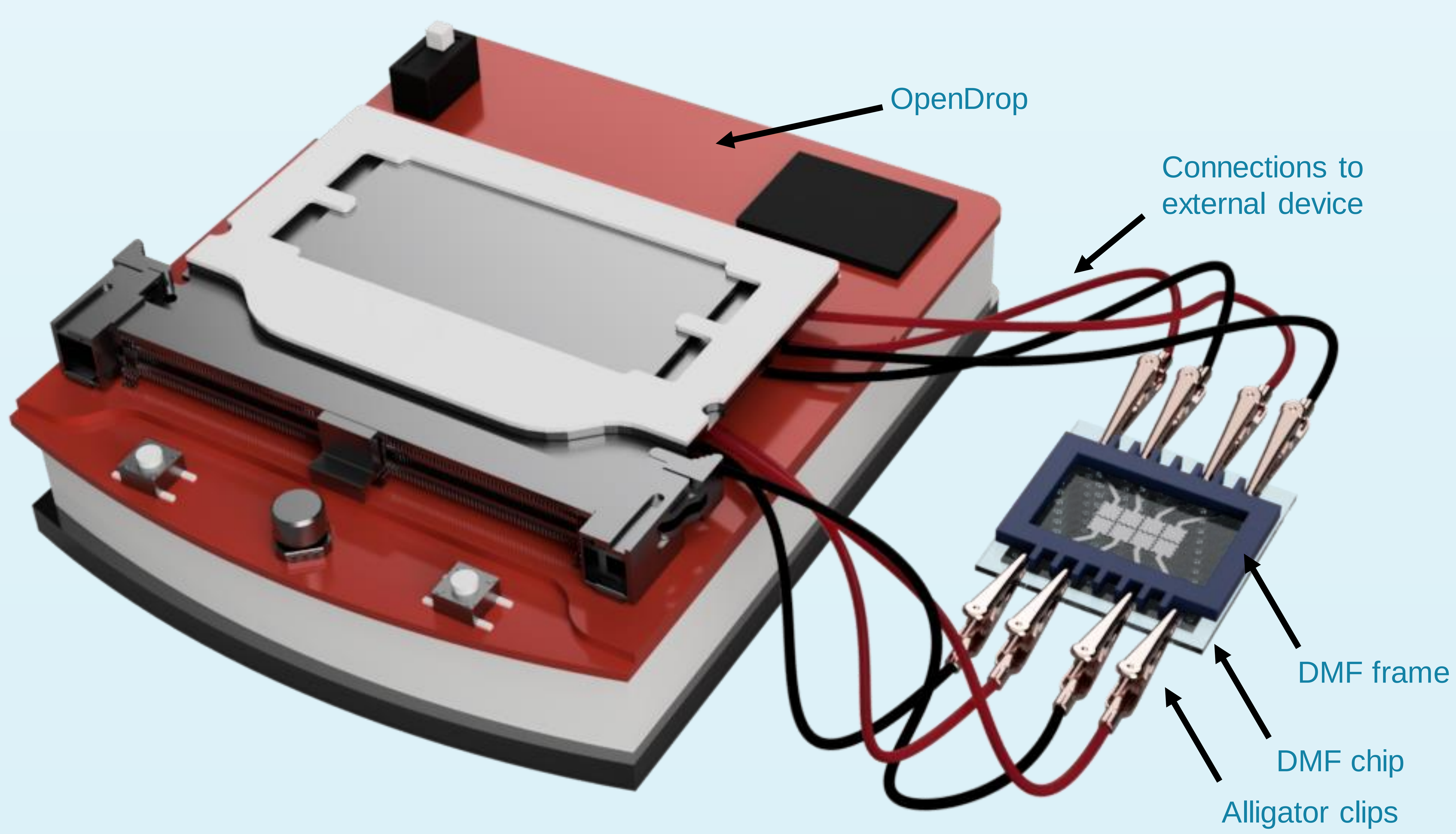
A digital microfluidic (DMF) device is a microfluidic technology based on the principle of electrowetting with the ability to control the movement of liquid droplets over an array of electrodes [1]. The droplet can be translated, merged, and split using different sequences of electrode activation. Thus a DMF device is a platform which can automate chemical processes with small quantities of reagents [1].

The OpenDrop, an open source digital microfluidics platform, was used in this project as a control device and voltage supply for the custom digital microfluidic chip [2]. The OpenDrop electrode array and typical DMF devices are fabricated on a PCB with gold-coated electrodes, therefore, non-transparent [2].

Project Goals

The goal of this project was to design and fabricate a transparent digital microfluidic chip capable of translating droplets of viscous liquid. The custom digital microfluidic chip was required to:

- Have at least 50% light transmission at the selected wavelength
- Translate a viscous droplet at 60 mm/sec
- Manage up to 15 uL of liquid per electrode
- Withstand up to 240 VDC



Design

The custom digital microfluidic chip was designed using four materials layered on top of each other in the following order:

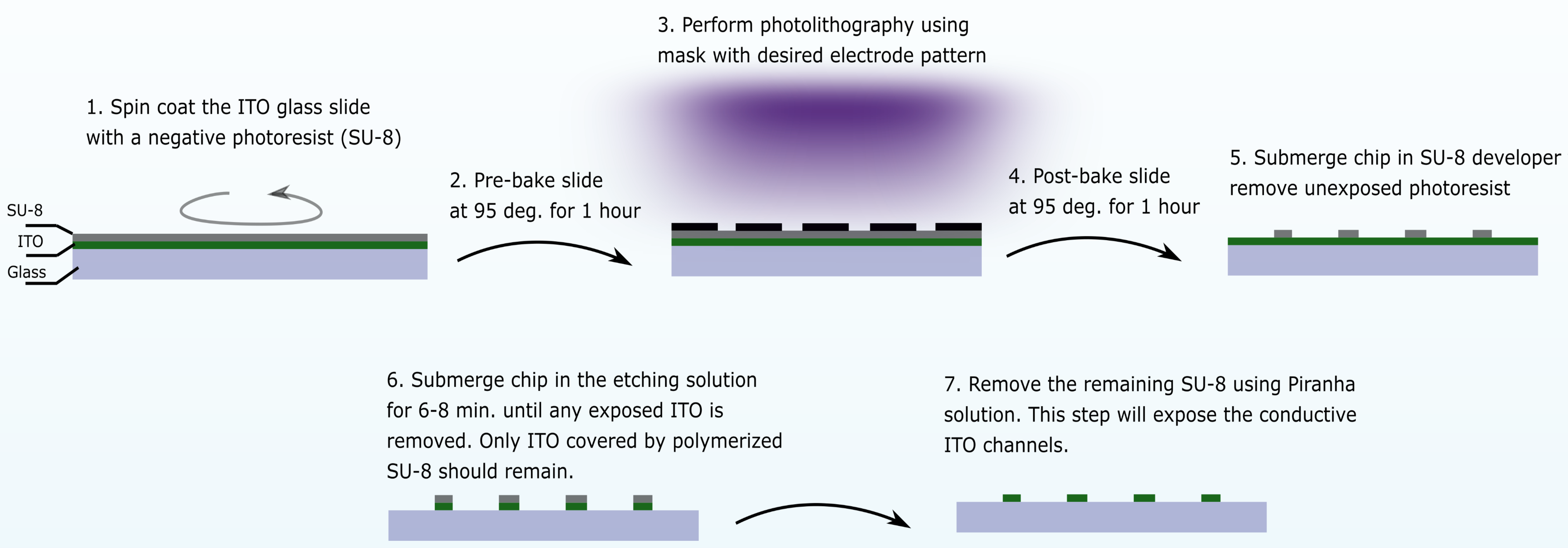
Layer	Material
Substrate	Glass was used to ensure optical transparency
Electrodes	Indium tin oxide (ITO) was used for its excellent optical transparency and conductivity
Dielectric	Parafilm M was used due to its transparency, pliability, and availability
Hydrophobic Coating	A small amount of PDMS oil was used as a hydrophobic coating on top of the dielectric to increase the droplets contact angle

The electrodes were patterned following the same layout as the OpenDrop. Slight overlap between the electrodes was an important feature to ensure droplet actuation.

Voltage channels were used to connect the electrodes to micro-alligator clips in order to supply voltage to the electrodes. Voltage channel widths were designed to be 0.6 mm, following the widths used by OpenDrop. Theoretical calculations showed that increasing the channel width resulted in decreased resistance.

A custom 3D-printable comb was designed and manufactured to isolate micro-alligator clips to prevent short-circuiting. The comb was designed to fit over future iterations of electrode chips to simplify future workflow.

Manufacturing Process



Results

An experiment to determine the optical transparency of the device at the selected wavelength was performed, finding 59% light transmission, or 41% light reflectance.

Resistance was measured along the ITO channels and was determined to be 150 Ω, compared to the expected value of 180 Ω [3]. However, minimal voltage drop was recorded when wiring the OpenDrop to the custom chip; only 3-5 volts were lost on average.

Droplets were not able to be consistently moved from electrode to electrode on the custom DMF. This was potentially due to the manufacturing of the chip not having enough overlap between electrodes.

Droplet actuation speeds were not able to be measured due to time constraints on the project; however, further work to obtain these results is discussed in the recommendations section.

Conclusion

By using the manufacturing methods discussed in the Design section, a transparent chip was created with minimal power and voltage loss. The optical properties of the chip surpassed the original target. The theory and calculations behind the design were valid, however, the manufacturing process may have introduced some error that led to a discrepancy from the expected results. Liquid droplets were not able to be consistently moved from electrode to electrode, leaving room for future work.

Recommendations

Based on testing results, the following items should be examined more thoroughly:

- Revise electrode design for optimal overlap of edges
- Use elastomeric connectors (zebra stripes) instead of micro-alligator clips to allow for more freedom in voltage channel paths

Also, the use of transparent printed circuit board (PCB) manufacturing may allow for a larger array of electrodes to be used, therefore increasing the overall utility of the device.

The temperature control of the custom DMF is an important factor to ensure proper viscosity of liquids being moved. Both heating and cooling options should be explored for future iterations of the chip.

Finally, to improve light transmission, alternative dielectric layers should be investigated.

References

[1] K. Choi, A. H. C. Ng, R. Fobel, and A. R. Wheeler, “Digital microfluidics,” Annual Review of Analytical Chemistry, vol. 5. Annual Reviews , pp. 413–440, 18-Jul-2012, doi: 10.1146/annurev-anchem-062011-143028.

[2] “OpenDrop – Desktop Digital Biology Laboratory.” [Online]. Available: http://www.gaudi.ch/OpenDrop/. [Accessed: 19-Jul-2021].

[3] “Indium tin oxide coated glass slide, square surface resistivity 8-12 Ω/sq | 50926-11-9.” [Online]. Available: https://www.sigmaaldrich.com/CA/en/product/aldrich/703192?cm_sp=Insite-_-caContent_prodMerch_gruCrossEntropy-_-prodMerch10-1. [Accessed: 17-Jun-2021].