Micro-Milled Poly Methyl Methacrylate Microfluidic Chip

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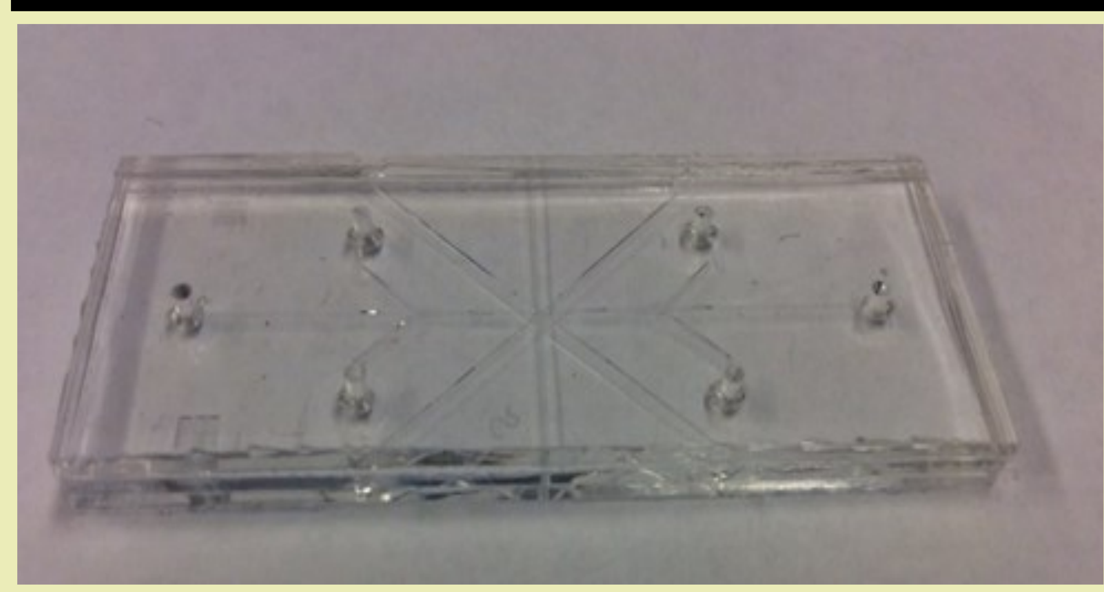
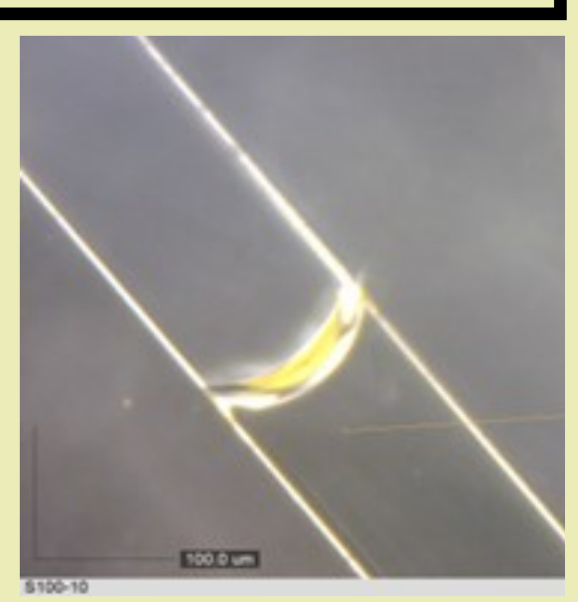
Introduction

Flow cytometry is the analysis of particles in a stream of fluid through the use of lasers. This analysis varies from determining the number of particles in a fluid to investigating the nature of each particle. Recently, microfluidic chips have been developed as an alternative to the previously larger and more expensive equipment. While these chips are more practical to use, they still pose issues for researchers. Our objective was to refine the design and manufacturing of this chip to eliminate the problems that has impeded work in the past.

Original Chip

The original microfluidic chip was composed of two molded Polydimethylsiloxane (PDMS) layers attached together. Liquid PDMS was poured onto a silicon mold of narrow channels, 390 µm wide, and was allowed to solidify. Two of these gel-like layers were attached to form channels that allowed liquid to flow through. The chip had three inlets: one for the sample fluid, and two for the sheath fluid used to condense the sample for analysis. Small chevrons on the top and bottom of the channels were incorporated to also condense the sample fluid.





Cons of Original PDMS Chip

While the original PDMS chip was effective in its function, it was inconvenient to use repetitively. The most apparent issue was the inability to clean the chip once the channel became clogged. The two layers were permanently fixed, so the chip was no longer usable once a channel became blocked. Making the original chip was also problematic. The silicon wafers used to mold the chip were fragile and expensive to make, so revising and testing new designs would prove costly.

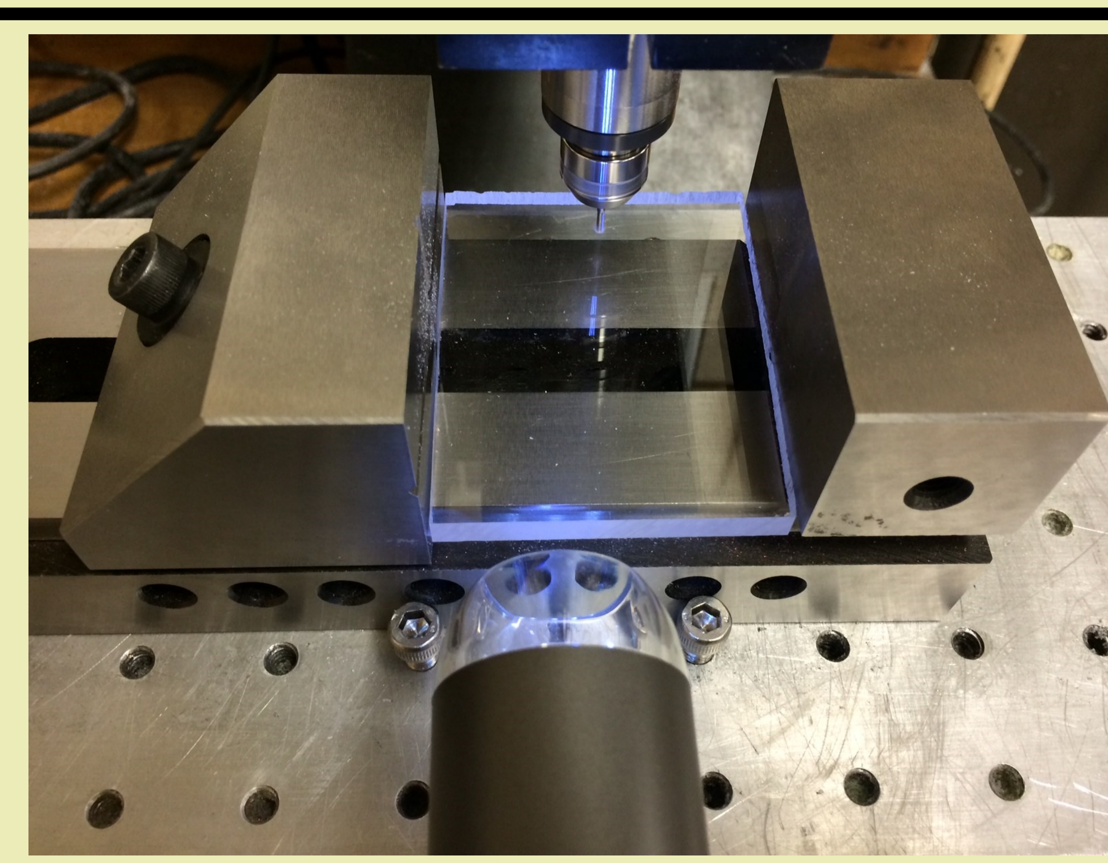
Design Objectives

The two layers of the new chip were to be detachable to allow cleaning. It should be easy to manufacture. The channels of the new chip are to be able to retain fluid flowing without impeding the flow regimen.

Alternatives

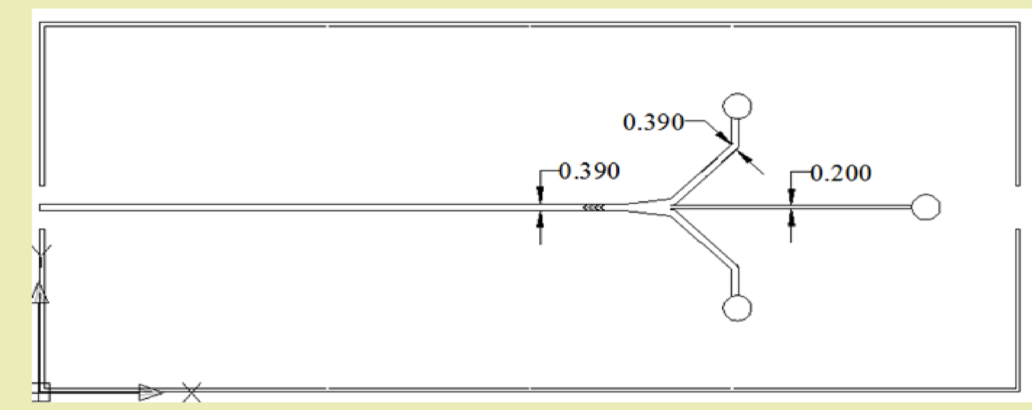
Option 1: We considered using a three layer structure to achieve our objective. The top and bottom layers would be poly methyl methacrylate (PMMA), and the middle layer would be made of PDMS. All three layers would be held together with six screws. Fastening the layers with screws would allow the chip to be taken apart, cleaned, and reused. The channels and chevrons would be micro-milled into the bottom PMMA layer. The middle PDMS layer is used because the flexible PDMS would provide a fluid tight seal for the channels. The top PMMA layer was used to give the screws a rigid base to hold the chip together.

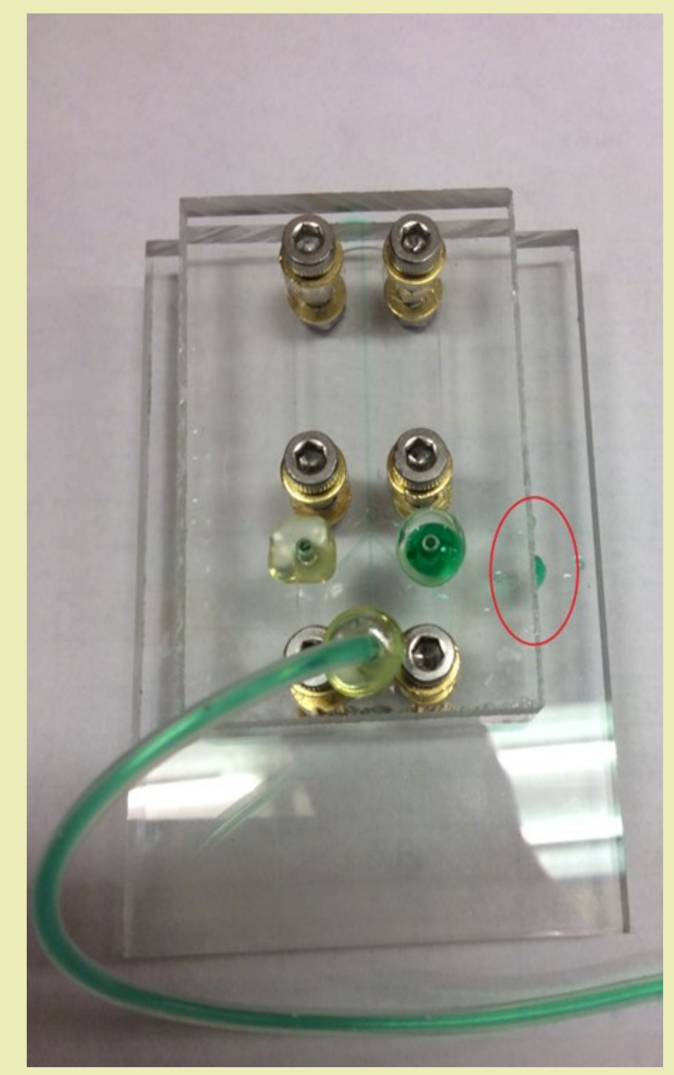
Option 2: We also considered the possibility of simplifying the design and eliminating the middle PDMS layer. The channels would still be micro-milled into bottom sheet, and held together with six screws. While this design may not be as water tight because of the two rigid PMMA plates that provide the seal, it would eliminate the possibility of channel deformation because of the compressed PDMS.



Design of New Chip

The design that was determined to be the best option was the simpler two PMMA layer design. The dimensions of the micro-milled channels are shown below.





Conclusion

This design was determined to be the best option because it achieved all of the objectives of the project. Micro-milling the channels simplified the manufacturing process. Micro-milling the channels makes changing their design far more cost effective and simplistic as all it entails is writing the G-code for the machine for the initial cut. To make modifications to the design, all that needs to be done is to make changes to the original code. Though it was initially a concern, the two PMMA faces did provide a sufficient seal to retain fast flowing water.

Continued Improvements

The tests for how well the chip holds water were conducted using colored water. While the seal retained water, it did not retain the less viscos fluid that will be used in actual flow cytometry tests. Work to improve this seal is continuing. Micro-milling provides a cheap and efficient method for inscribing the channels into the chip, however it leaves a rough surface for the fluid to flow over. This issue could possibly be solved through the use of thermo-cycling or a solvent to reduce roughness.

Acknowledgments

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