PDMS Microfluidic Chip Fabrication

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Abstract

We designed a microfluidic chip in AutoCAD, but due to time issues we used premade SU-8 and Polycarbonate master. We also tested 3D printed resin as a master material. This report focuses on our PDMS (Polydimethylsiloxane) lab work and describes the overall workflow of the mixing, degassing and casting process.

1 Introduction

Microfluidic chips are prototyped by creating an SU-8 master from CAD designs, then casting PDMS. We performed the CAD design and all PDMS steps. The master fabrication was skipped due to time issues, the report therefore only briefly touches that process.

2 Materials & Methods

2.1 CAD Design

To cast a microfluidic chip, we need a master. The design is created using AutoCAD. The following images show the unit operations included in the first chip design. The inlets are all $300\,\mu$m in diameter, according to the best practices stated in the lecture. The channels have a $100\,\mu$m width (except the laminar flow module: $200\,\mu$m). Since SU-8 Photoresist will be used for the master and there channel heights between 200 and $500\,\mu$m are possible. Therefore being in accordance with the 1:10 rule. [1, 2]

Figure 1 shows a simple demonstration circuit for laminar flow analysis on microscopic scales. The two inlets allow the usage of two differently colored fluids that will merge into one channel. This lets the operator view diffusion effects under the microscope, while laminar parallel flow of the fluids remains. [1]

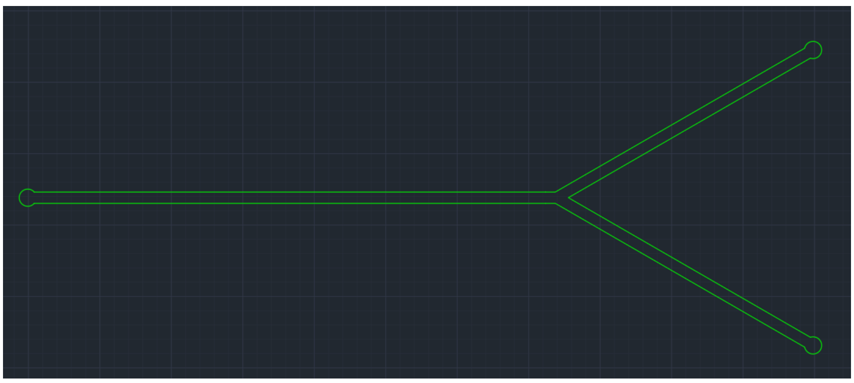

Figure 1: Laminar flow demonstration with two inputs and one output.

The design also includes a mixer element with two inlets that merge into one outlet. Figure 2 shows the meandering structure to mix two fluids.

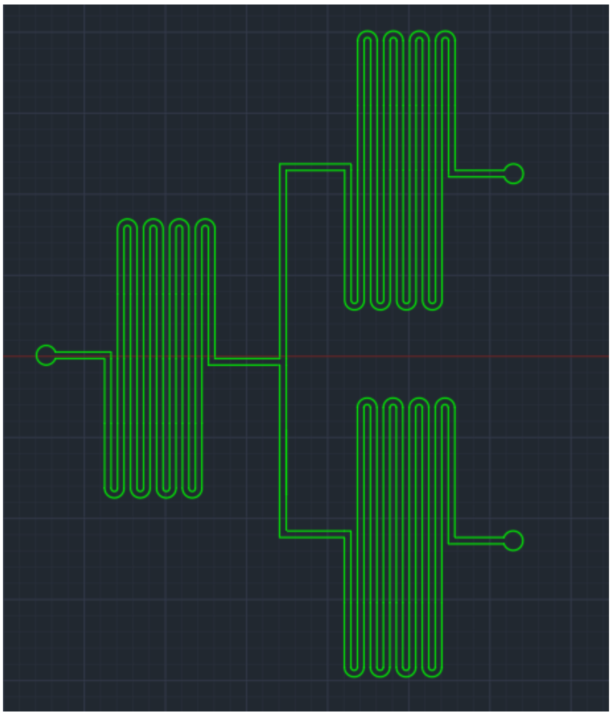

Figure 2: Three mixers with two inputs and one output.

The last Element included in the Design are two tesla valves. They have the same dimensions, but opposite directions. This allows the comparison of flow dynamic. In forward direction the fluid should not be slowed down. Operated in reverse direction though the tesla valve demonstrates a diodicity behavior, because of the increased resistance. It can be used as a passive check valve. Figure 3 shows the AutoCAD design. [1]

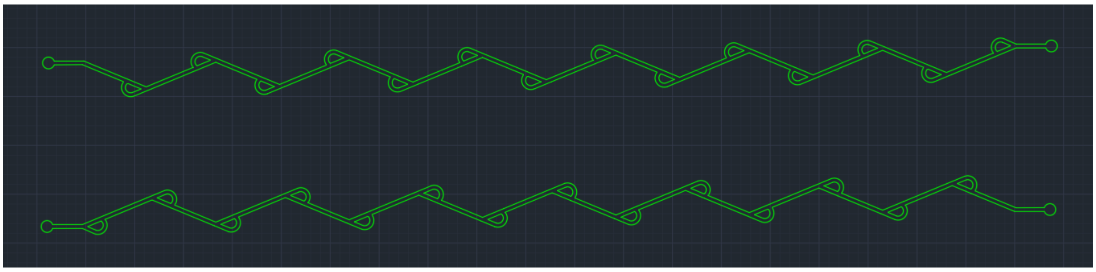

Figure 3: Two tesla valves in opposing directions.

2.2 Master Fabrication

The DXF-Files designed with AutoCAD could be used to write soft lithography mask with the μPG (micro-pattern generator) of the IMM Lab. Figure 4 shows the complete Chip design with all Layers. The Substrate layer is bright blue. It has the dimension of a 75 x 25 mm microscope slide. In bright green there are the structures that should be included in the mask. The outline of the wafer is represented by the yellow layer. [1]

To fabricate the master a mask is necessary for the soft lithography process. First one Spin-coats a Si-wafer with SU-8 photoresist to the desired height. The photoresist is then exposed to UV light through the mask. Then the wafer undergoes a post-bake to harden the photoresist

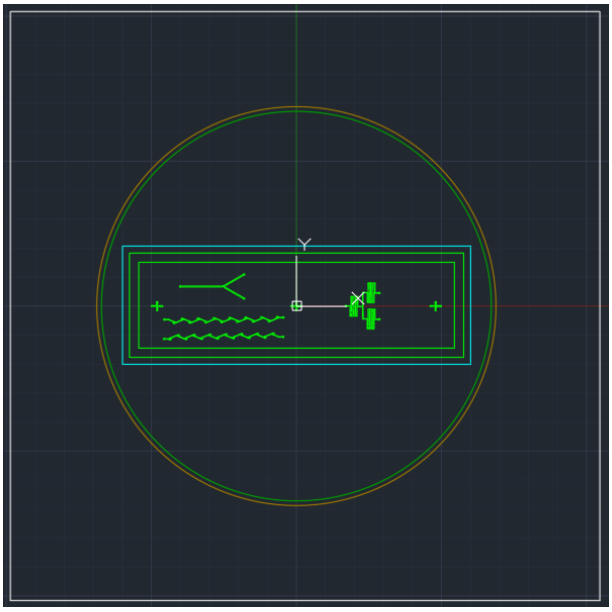

Figure 4: Complete AutoCAD Design with all Layers.

and is then the exposed fields get develop and dissolve. Only the intended structure of the master remains.

2.3 PDMS Lab Work

2.3.1 Materials

The following list contains all the necessary materials and chemicals.

- SU-8 master (or other masters)
- Sylgard 184 PDMS kit (base + curing agent)
  - mixing cups, spatula
  - 10 ml syringe
  - 5 ml pipette
- Vacuum desiccator, silicone grease
- Membrane Vacuum pump CR-MV100
- PSE - personal safety equipment
  - Protective gloves
  - Lab coats
  - Safety glasses
- Oven for PDMS baking
- scalpel for chip extraction

2.3.2 Mixing

Sylgard 184 PDMS base and curing agent were combined at a 10:1 volume ratio. The base was extracted with a 10 ml syringe and the curing agent added with a pipette. The mixture of 10 ml base and 1 ml curing agent was stirred for 1 min until visually homogeneous. The Substances need to treated according to the safety datasheet. Using a Aluminum foil to protect the surface from spills is highly recommended because of the high adhesiveness of PDMS. [3]

2.3.3 Degassing

To remove the air bubbles and achieve a clear result the PDMS mixture needs to be degassed. Otherwise the bubbles cause reflections in the hardend chip. Therefore the mixture is put into a vacuum desiccator for 30 min or till all the bubbles are removed. Its important that the vacuum pump is not too strong, because it could suck the air out to fast and let the mixture overflow. Therefore only a 100 mbar membrane vacuum pump is used. After achieving the 100 mbar vacuum the pump can be shut down if the desiccator is sealed properly. Silicone grease is used for the support surface of the desiccator lid and pot.

2.3.4 Casting & Curing

After degassing the PDMS can be casted by gently and slowly pouring it into the master. Since this pouring step also introduces new air bubbles, by trapping them between master and PDMS, a second degassing step would be highly recommended. Timing issues caused us to stop the process there and let it cure on its own till the next lab experiment. Otherwise the PDMS would've been heat cured at 150 °C for 10 min in a oven. The PDMD replica could then be cooled and peeled off. [3]

3 Preliminary Observations

Base and curing agent are both clear substances. Mixing made them turbid, because a lot of air bubbles were produces. In the vacuum desiccator the mixture produces even more bubbles that slowly rise to the surface. After degassing the PDMS is clear. Pouring it on the master introduced some small air bubble and pouring it to fast traps bigger bubbles between PDMS and master.

4 Future Work

To improve the current workflow the before mentioned steps should be introduced. Degassing the SU-8 master with the PDMS cast could further improve the chip quality. Heat curing would speed up the process further. Next we'll test the quality of the chips on the three different master substrates. One SU-8 resist and PC master, as well as the 3D printed resin structures for testing purposes.

References

[1] Prof. X. Li, "Lecture on Microfluidics and Lab-on-Chip," *Fraunhofer IMM & HSRM*, 2025

[2] Stanford Microfluidics Foundry. *Basic Design Tips*. Available at: `https://www.stanfordmicrofluidics.com/design-basics`. Accessed: 29 June 2025.

[3] Dow Inc. *SYLGARD™ 184 Silicone Elastomer Kit*. Available at: `https://www.dow.com/en-us/pdp.sylgard-184-silicone-elastomer-kit.01064291z.html#overview`. Accessed: 29 June 2025.