Microfluidics (40 points)

Objective: The objective of this online lab is to gain knowledge and experience creating microfluidic devices. In this online lab a master mold will be used to create microfluidic structures in PDMS

The student will watch a series of videos pertaining to the microfluidics process. These videos will provide detailed insight onto each step of the microfluidics process. After watching the videos the student will be required to answer review questions on ANGEL.

Background:

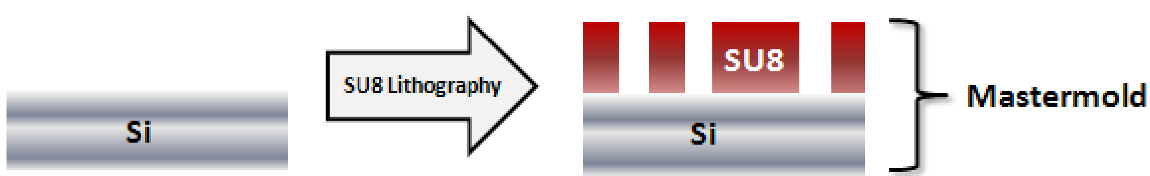
Microfluidics is a broad term used to describe different applications of fluid transport through channels and networks in the micron regime. A microfluidic channel is typically defined as a channel having one or more dimensions less than 100 microns in size. The transport mechanisms by which liquids are transferred include capillary forces, hydrostatic pressure gradients, electrokinetics, pumps, magnetism, and digital arrays. Even more novel ways to move fluids are being created, with material selection an important aspect to consider when deciding on the transport mechanism. Some of the earliest recorded electrokinetic microfluidic studies utilized silicon substrates but the expense and need for insulating the surface has shifted the focus to plastics and glass. In this lab, we will describe the fabrication issues involved with these devices and show the application of hydrostatic transport of a liquid media.

Experiment:

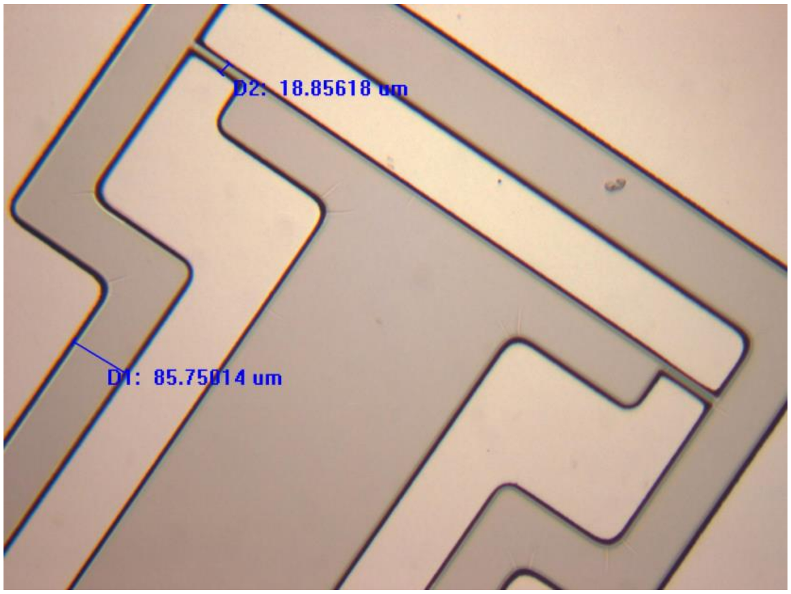
In this lab a functional microfluidics device will be created by using a PDMS cast from a master mold. The PDMS cast and glass substrate will be prepped, activated, and bonded together to allow fluid flow. A needle inlet will be placed using epoxy, and dyed DI water will be observed under an optical microscope as it flows through both the small and the large channels.

Step 1: Mastermold fabrication

The first step in creating a microfluidics device is to create a mastermold using negative lithography. This is an extremely important step since the quality of the mastermold will dictate the quality of the device and therefore all features defined using this process. The mastermold fabrication process is depicted below:



Below is a bright field microscope image at 10 X magnification of patterned SU-8 of the mastermold for the “T” shaped microfluidics device. The brighter areas correspond to the silicon wafer and the darker areas correspond to areas where there is SU-8 photoresist. This image shows that the small channel of the mastermold has a width of approximately 18.9 µm and the large channel of the mastermold has a width of approximately 85.8 µm.



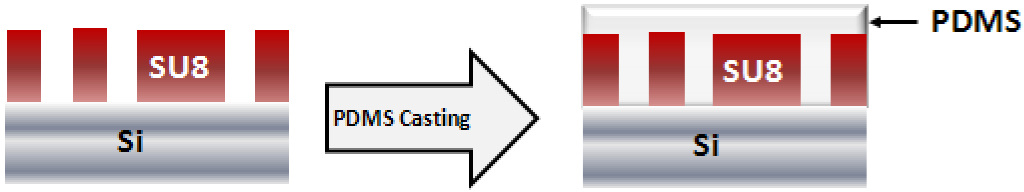
To see a master mold fabrication process, refer to the online video for creating the microcontact master mold.

Step 2: PDMS casting

The second step in creating a microfluidics device is to pour (cast) the PDMS over the mastermold. Polydimethylsiloxane (PDMS) is an organic silicone based polymer. PDMS has several properties that make it useful for micro and nanofabrication including its relative inertness, chemical and mechanical stability over time, pliability, the fact that it is a fluid at ambient pressures and temperatures prior to curing, and a number of other features each important for different applications of the material.

Uncured PDMS’s viscoelastic flow allows the material, given appropriate time and temperature, to fill in and conform to extremely small dimensions, on the order of 10’s of nm. The polymer is made by mixing an elastomer bulk and curing agent together. Curing time can be decreased by hours with the addition of heat or vacuum. There are a number of formulations of PDMS, each with specific properties for different applications. The PDMS used to make the microfluidic device is Dow Corning Sylgard 184®. Depending on the type of PDMS and the curing temperature, PDMS can shrink from 1% to 3%.

The PMDS casting step is depicted below:



Watch the mixing and the application of the PDMS at the link below:

To see mixing and PDMS application steps, refer to the online video for PDMS casting a microcontact master mold.

Step 3: PDMS and substrate preparation

In the next step, the PDMS microfluidic devices and glass substrates were prepared for adhesion. Once each of the devices were removed from the mastermold and measured, access points to the channels were punched through. Both the PDMS and glass substrate were sonicated in ethanol and dried with nitrogen. The PDMS and glass substrate were then activated, PDMS was applied to the glass substrate channel side down, and the two were allowed to bond.

Watch the PDMS and substrate preparation steps at the links below:

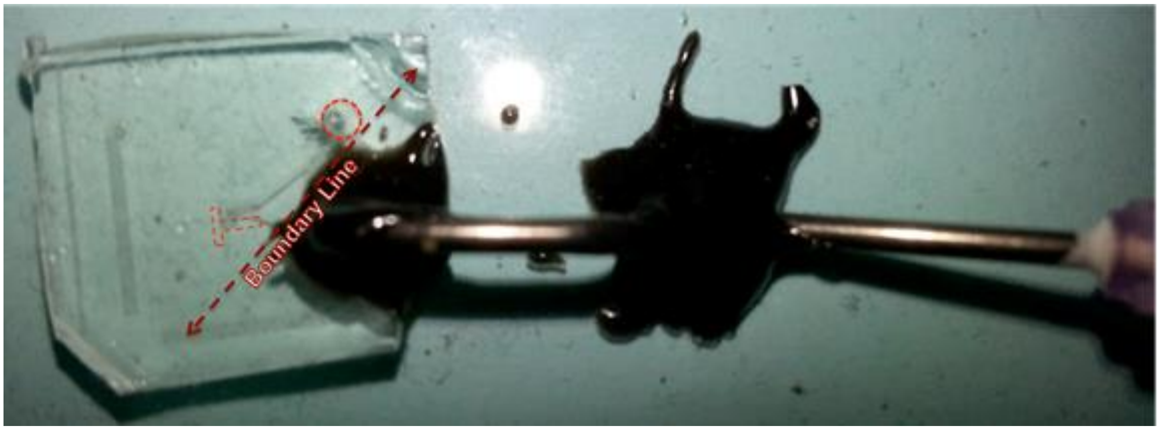
PDMS preparation:
http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=df3ad28c-76c9-43b4-87c4-7

Ozone activation:
http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=e9baaea3-fc98-4ad1-b8a5-7

Step 4: Functionalizing the device

In the next step a pre-bonded device was obtained and an 18 gauge needle was bent into a question mark shape and glued using quick set epoxy into the device inlet as shown below:

Special care was taken not to cover the “T” shaped microfluidic channels with epoxy as shown in the example below. If the epoxy does not indent when touched with tweezers it has been fully cured.



The following link depicts needle placement for channel inlet:

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=47581939-ae3c-43fd-aeba-9

Step 5: Testing the device

In the last step of the process the device is tested for functionality. Approximately 3 mL of dyed DI water is collected in a syringe with flexible tubing and connected to the needle of the microfluidic device. Pressure is applied to the syringe and flow through both the large and small channels is observed under an optical microscope. It is important to note the flow profiles both within the large and the small channels.

Below are videos depicting testing of the device as well as an optical microscope video showing the feature dimensions and parabolic flow profiles through both the large and small channels of the functional PDMS device:

Device Testing:
http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=2297bf56-4385-4ad7-b321-c

Fluid flow:
http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=d4c9fa63-eb3c-4784-b928-f

Questions to be answered on ANGEL (NO HARD COPY REQUIRED)

1. What process is used to create the master mold used to make the microfluidic devices? (3)

2. How thick is the photoresist layer used to create the master mold expected to be? (3)

3. Which of the following is not a reason why PDMS is used for microfluidic devices? (3)

4. Which processing step activated the PDMS and glass substrate allowing efficient bonding? (3)

5. Which of the following is a correct chemical description explaining how activation and bonding occurs between PDMS and glass substrate? (4)

6. Which of the following are the correct parameters involving sonication in reagent alcohol? (3)

7. What chemicals compose the reagent alcohol? (3)

8. For how long was the PDMS allowed to bond to the glass substrate after placement before continuing to the next step? (3)

9. Which of the following is not a correct statement involving attaching the inlet to the device with epoxy? (3)

10. Which of the following mechanisms of fluid transport through a microfluidic device is described as fluid flow driven by the interactions between the walls of the channel and the cohesion in the liquid? (3)

11. The mechanism of fluid transport that was used with this microfluidic device was: (3)

12. When looking at the video explaining of fluid flow through the large and the small channels of the functional PDMS device, which statement correctly describes what is observed? (3)

13. Why might the channel dimensions of the PDMS device be different from the channel dimensions of the mask itself? (3)