

Zarelab Guide to Microfluidic Lithography

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Introduction

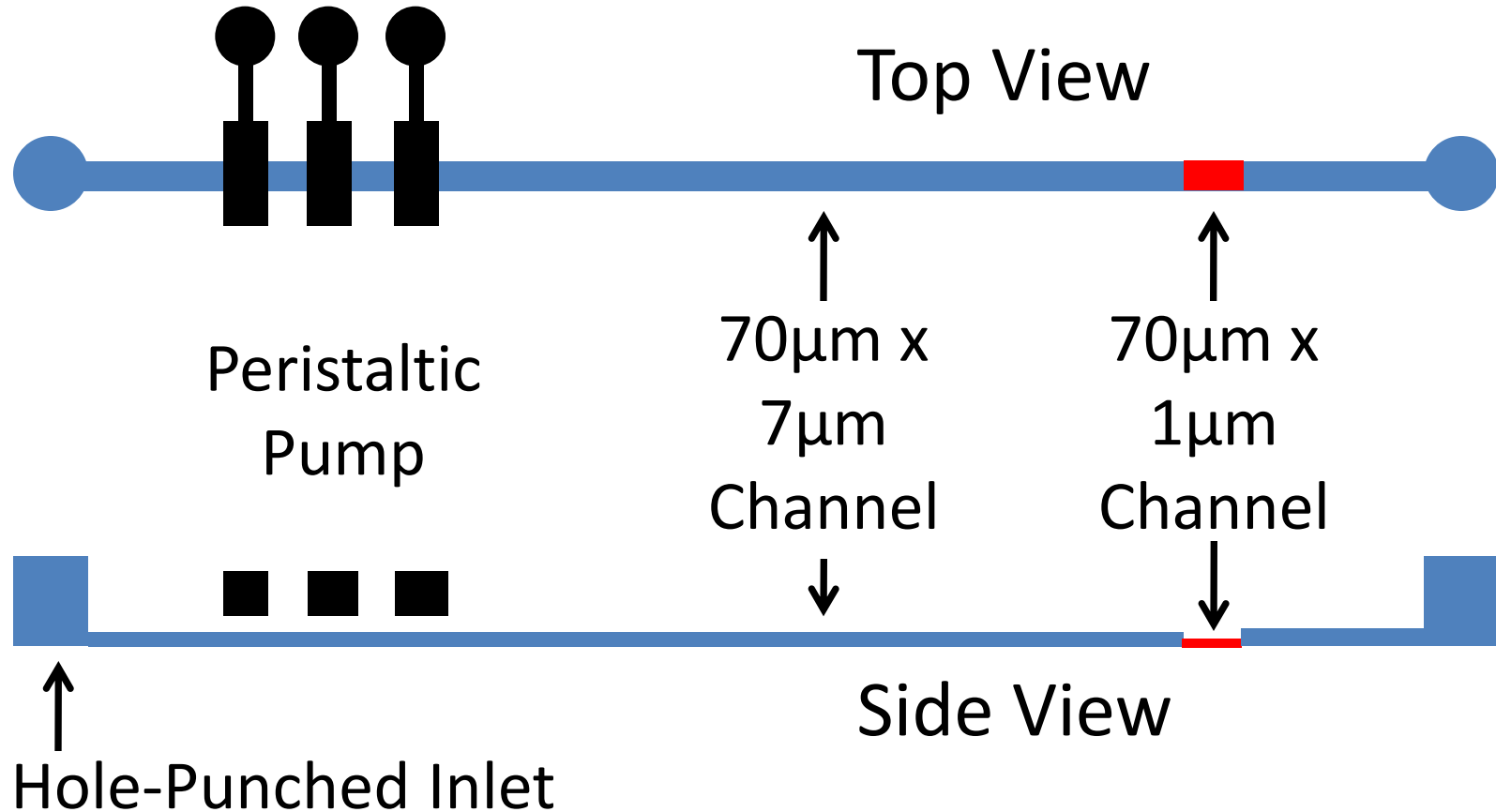
The process through which we make microfluidic chips is called *lithography*. This presentation is an introduction to how we do lithography in the Zarelab.

There are actually two types of lithography involved in making a microfluidic chip:

- *Photolithography*: Making a mold on a silicon wafer using UV light to etch a design
- *Soft lithography*: Using the mold to make a chip from polydimethyl siloxane (PDMS) polymer

Sample Chip Design

We start with a chip design. Below is a simple sample design that we'll be using as an example.



Part I: Photolithography

Photolithography

The purpose of photolithography is to create small structures or *features* on a silicon wafer using *photoresist*. Features are made out of photoresist by *etching* with UV light.

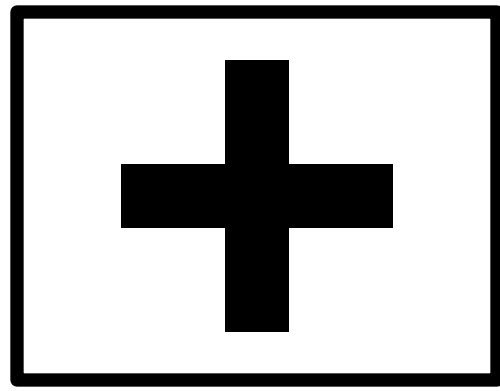
Photolithography uses this general process:

1. Wafer priming
2. Spincoating
3. Prebaking
4. Exposure
5. Development
6. Postbaking (varies depending on resist type)

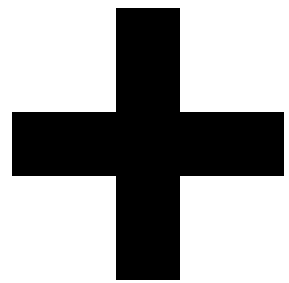
Photoresist

There are two types of photoresist:

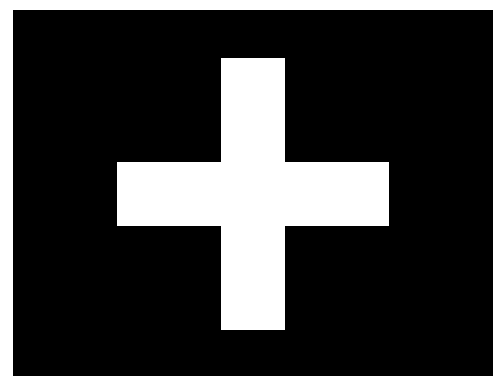
- **Positive**: Exposure to UV light *removes* resist
- **Negative**: Exposure to UV light *maintains* resist



Mask



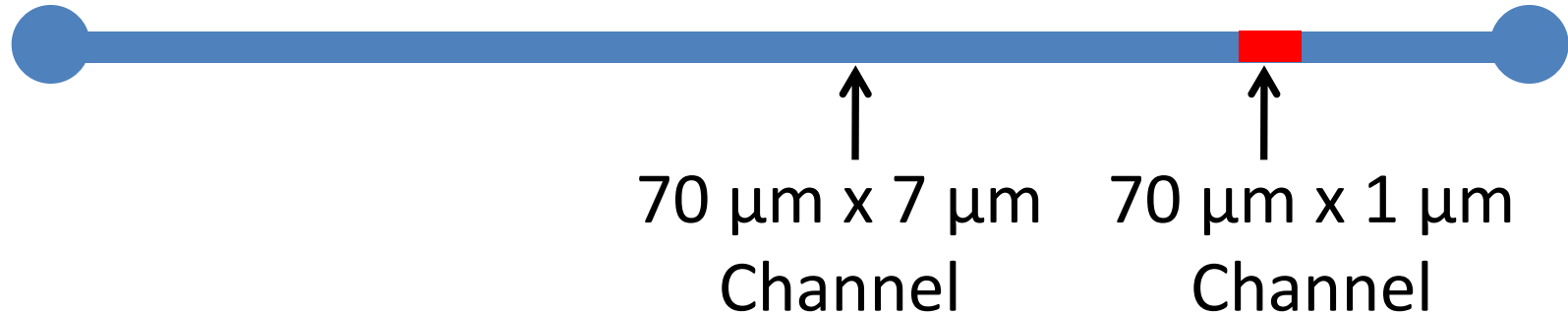
Positive
Resist



Negative
Resist

Masks

Prior to doing photolithography, we need to make *exposure masks* for our mold. These are used during the exposure step of photolithography to etch the desired design into the photoresist.



The channel mold has two different feature thicknesses: 7 μm and 1 μm. Therefore, we need two separate masks for the two different resist layers.

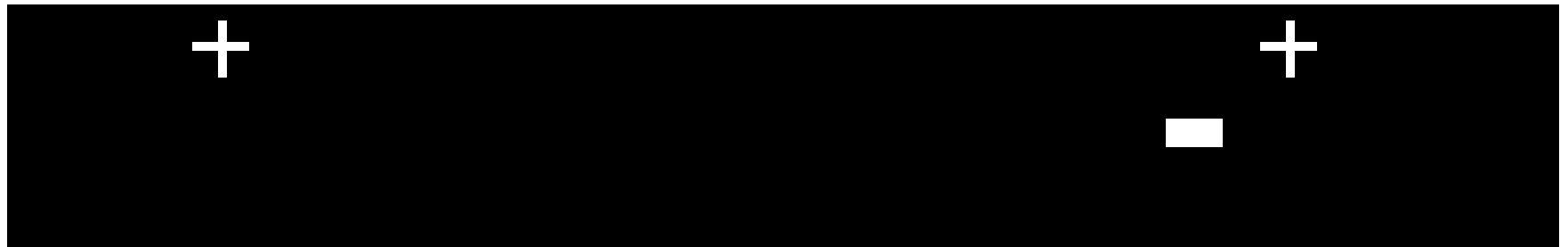
Masks



Mask for 7 μm -thick Positive Resist Layer



Mask for 1 μm -thick Negative Resist Layer



The crosses are *alignment marks*. They are used to align the mask for the second layer to the features of the first layer.

Negative Resist Photolithography

We've made two masks because the wafer has two feature *layers*: a 7 μm positive resist layer and a 1 μm negative resist layer.

Question:

Why do we first make the negative resist layer?

Answer:

Exposing the negative resist to light a second time (during the positive resist exposure) does nothing. Exposing the positive resist to light (during the negative resist exposure) would further etch it.

Negative Resist Photolithography

Step 1: Wafer Priming

All wafers need to be *primed* with HMDS to increase adhesion of the photoresist to the wafer. This can be done either in the *yes oven* or *svgcoat* track.

Step 2: Spincoating

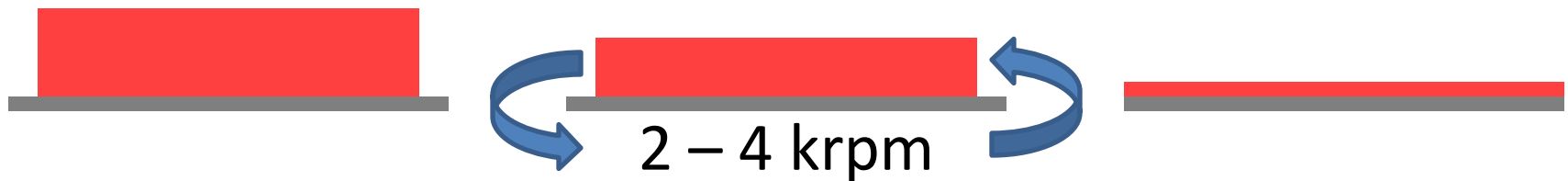
The wafer is placed on a rotating platform, or “chuck”, and held via vacuum suction. Resist is poured onto the wafer. The wafer spins at high speed (several thousand rpm’s). The speed determines the resist thickness.

Negative Resist Photolithography

Step 2: Spincoating (cont.)

For negative resist, we use SU-8. It comes in various concentrations for different resist thickness ranges. Please refer to www.microchem.com for more info.

We use the *headway2* instrument for negative resist.



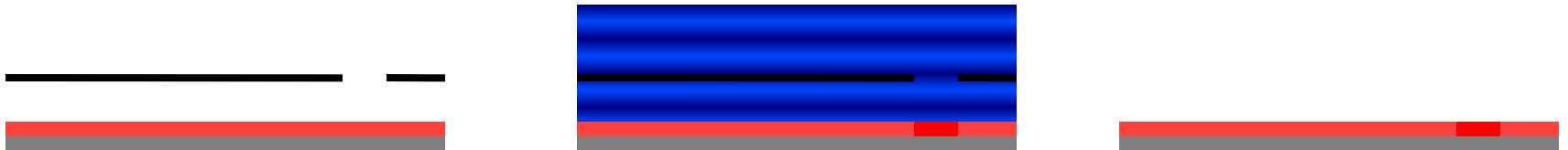
Step 3: Prebaking

Following spincoating, wafers need to be baked on a hotplate. Refer to the SU-8 data sheets at www.microchem.com.

Negative Resist Photolithography

Step 4: Exposure

Wafers are exposed to UV light using the *karlsuss* or *evalign* instruments. A mask is used to transfer the design to etch the design onto the spincoated resist. The energy and time required can vary with resist thickness, so refer to the SU-8 data sheets.



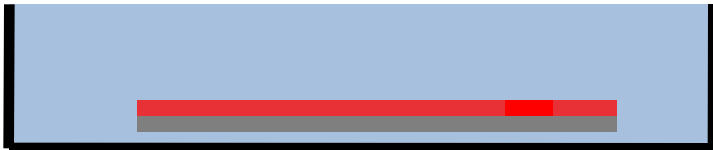
Negative Resist Photolithography

Step 5: Postbaking

Following exposure, wafers need to be baked on a hotplate again. Refer to the SU-8 data sheets for baking times.

Step 6: Development

Wafers are placed in SU-8 developer, which removes resist that was not exposed to UV light. Only the desired features remain. Development times vary with thickness, so refer to the SU-8 data sheets.



Positive Resist Photolithography

For all subsequent layers after the first layer, do NOT re-prime the wafer. Wafers with photoresist on them cannot be put in priming instruments.

Step 1: Spincoating & Prebaking

For positive resist (SPR 220), we use the *svgcoat* instruments. These are automated tracks where pre-set recipes are used for specific thicknesses. Different thicknesses require different prebaking strategies. Ask a section member for advice.



Positive Resist Photolithography

Step 2: Exposure

Once again, the *karlsuss* or *evalign* instruments are used for exposure. There are no reliable data sheets for SPR resist. Therefore, ask a section member for advice on what settings to try first.



Step 3: Development

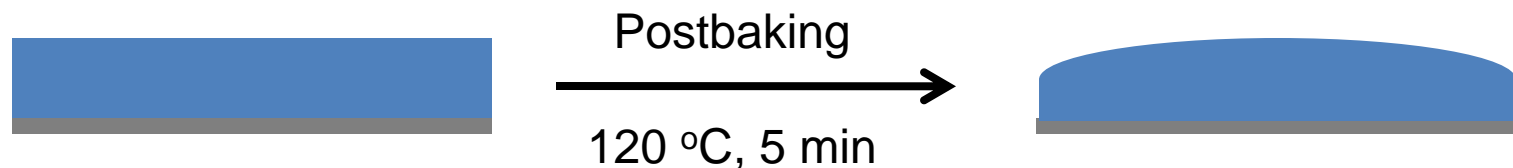
Use the automated *svgdev* tracks for positive resist.



Positive Resist Photolithography

Step 4: Postbaking (optional)

If your positive resist is a mold for a channel that will have a valve or pump above it (like in this sample design), you should postbake it. This curves the cross-section, which allows for complete closure of the channel.



Postbaking should be done at 120 °C for at least 5 min. Check the profile using a microscope.

If no valve is employed, there is no need to postbake.

Final Tips for Photolithography

- Before taking your wafers out of the SNF, check them under a microscope to make sure that the features came out the way you wanted.
- When you get back to the Zarelab, place the wafers in a dessicator under silanes for a half hour. This protects the photoresist from the degradation that comes from continued use.
- Be prepared to make multiple wafers. Normally, a few will serve to test parameters such as exposure time, as instrument parts like the UV lamp can change intensity and uniformity over time.

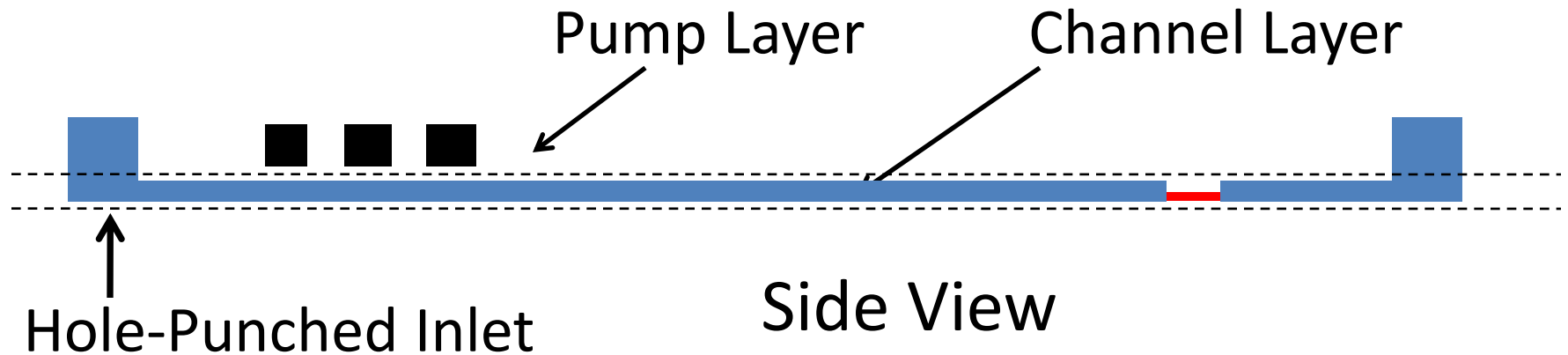
Part II: Soft Lithography

Soft Lithography

The molds we created using photolithography in the SNF can now be used to create microfluidic chips via soft lithography. Unlike photolithography, soft lithography can be conducted in our Bio-X lab.

There are a wide variety of soft lithography techniques. This part of the presentation will simply guide you through lithography of a very simple chip using basic techniques. If you encounter any soft lithography challenges or questions, ask the other section members. They will have more than a few ideas of how to proceed.

Lithography in Layers



Soft lithography is done in layers. In this chip, there are two: the 'pump' layer and the 'channel' layer. Each is made from a mold. We made the channel layer mold in the previous photolithography section. Assume that we've also made the pump layer mold.

Pump Layer

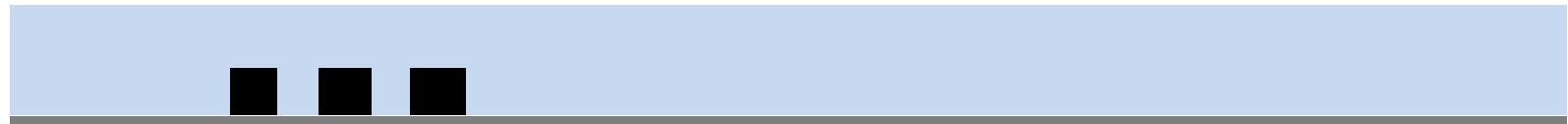
Step 1: Pump Layer



Mix 10:1 PDMS A:B and pour over the mold for the pump layer.



Place in the vacuum dessicator to remove all gas bubbles.



Completely cure at 80°C.



Pump Layer

Step 1: Pump Layer (cont.)

Cut pump layer from the wafer.



Using gloves and a hole punch, create inlets for the three pump valves.

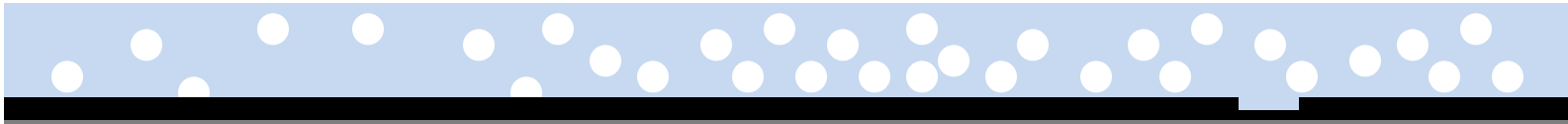


Channel Layer

Step 2: Channel Layer



Mix 10:1 PDMS A:B and pour over the mold for the channel layer.



Spincoat PDMS on the wafer at the appropriate speed for the desired thickness.



Partially cure at 80°C.



Channel Layer

Step 2: Channel Layer (cont.)



Align the pump layer and press down onto the channel layer.



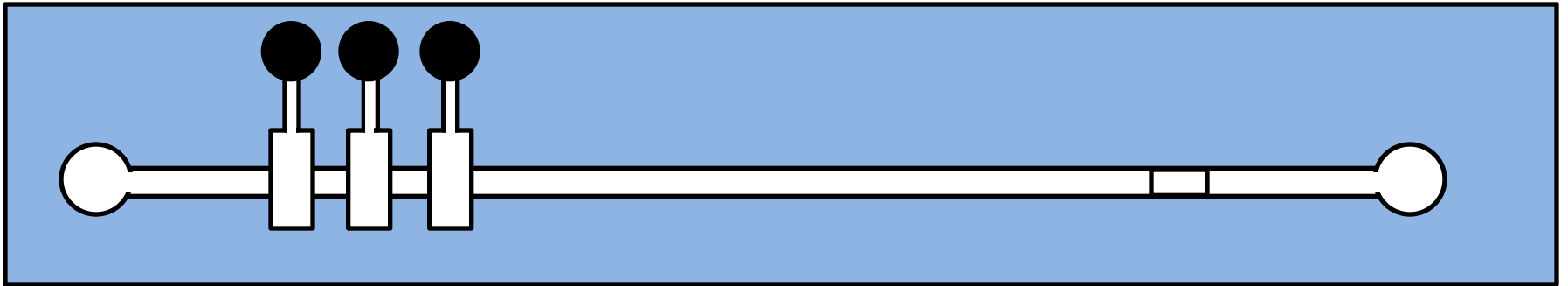
Completely cure the joined layers at 80°C.



Channel Layer

Step 2: Channel Layer (cont.)

Cut the pump-channel chip from the wafer.



Using gloves and a hole punch, create inlets for the two ends of the channel.



Coverslip

Step 3: Glass Coverslip

Mix 10:1 PDMS in cyclohexane in a 1:2 mass ratio.
Pour onto glass coverslip.

Spincoat PDMS/cyclohexane on the wafer at the appropriate speed for the desired thickness. The cyclohexane allows for a thinner layer.

Partially cure at 80°C.

Coverslip

Step 3: Glass Coverslip (cont.)

Partially cure at 80°C.

Partial curing requires removing the PDMS from the oven prior to cross-linking completion. The PDMS is still molten, though the degree can be greatly varied by the curing time. More molten PDMS can more strongly bond to a substrate, but it is also more susceptible to 'filling in' open structures (e.g. channels) and being distorted.

Coverslip

Step 3: Glass Coverslip (cont.)

Place the pump-channel chip onto the PDMS-coated glass coverslip.



Completely cure the complete chip at 80°C. It is recommended that the final cure be done overnight to ensure complete bonding.



Conclusion

This concludes the introductory guide to microfluidic lithography. Now that you have seen the process of making a chip, you should better understand the considerations that go into making a design.

Remember though that this is simply an introduction. Chip design and lithography are complex, nuanced subjects. Please shadow your fellow section members before doing your first lithography run. Also, when making a design, please ask them for input and advice.