A p p e n d i x

DESIGNING AN ELASTOMERIC MICROFLUIDIC CHIP

This section describes the procedure involved in designing an elastomeric microfluidic chip. The information comes from teaching micro-fluidics to grad students in Caltech course APh109 and my own research. This is also the procedure needed to use the ***Caltech Microfluidic Foundry*** (http://www.kni.caltech.edu/foundry)

First, two caveats – one, no one should assume that they can learn microfluidic chip fabrication from reading, any more than you can learn to ride a bi-cycle by reading a book. And two, this tutorial is restricted to designing multi-layer soft lithography planar chips made of PDMS. Other kinds of microfluidic chips are possible, but are not covered here.

The microfluidic chip-making process can be broken down into four steps:

1) Make a design and print a photo-mask.

2) Create photolithography molds.

3) Replica molding, alignment and bonding of PDMS layers.

4) Test the devices.

Here, I will concentrate exclusively on Step 1 because detailed procedures for the other steps are available elsewhere.

Mask Design

Mask Design is done using AutoCAD or other CAD software. We shall describe the procedure for AutoCAD and transparency laser printout from www.outputcity.com. The procedure can be modified for other software (Tanner, Cadence etc.) and other printout (for example, using a laser chrome mask printer).

Let's say you have a new idea for chip - it's a single layer T- junction and you draw it on paper. You want to split a fluid stream into 2. What dimensions should it be? Let's make the channels 100 microns wide. The height could then be selected to be ~10 microns, so that the aspect ratio is about 1:10. An aspect ratio of 1:10 will work fine, but an aspect ratio exceeding 1:20 usually results in collapse with PDMS, unless there are pillars to hold the channel up.


T junction
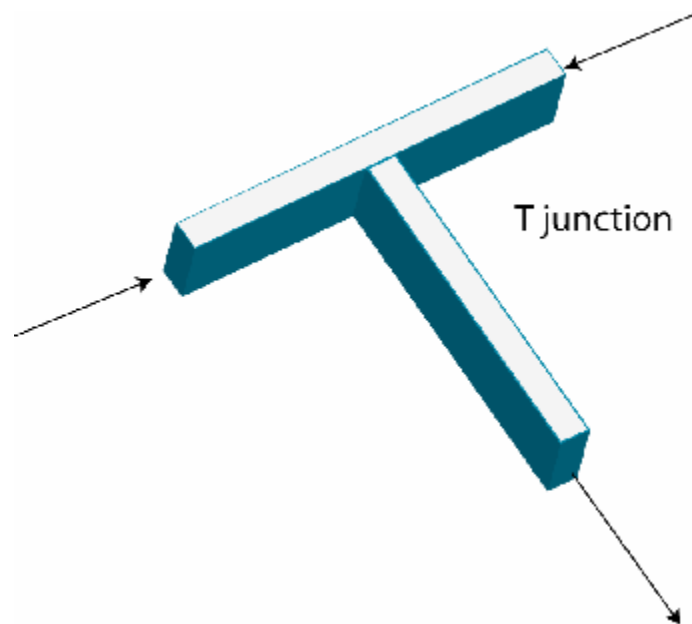
We will assume some very basic familiarity with AutoCAD. You can probably get used to it in 15 minutes. Open AutoCAD (any version beyond AutoCAD 2000). The following rules must be followed:

1) Select microns as the unit with 0 precision (à Format à Units)

2) Everything must be drawn using CLOSED POLYLINES.

3) Draw everything on a layer different from ZERO layer. Select a new layer and use it for drawing (à Format à Layer). Let's call out layer FLUID. Choose a color for the layer.

Three functions may be useful for your drawing ORTHO, SNAP and GRID. Find out about them. A circle of a square or a polygon IS a closed polyline in AutoCAD. Normally, the printing software will do the "hatching" for you – i.e. fill the polyline. Note these possibilities for conversion:
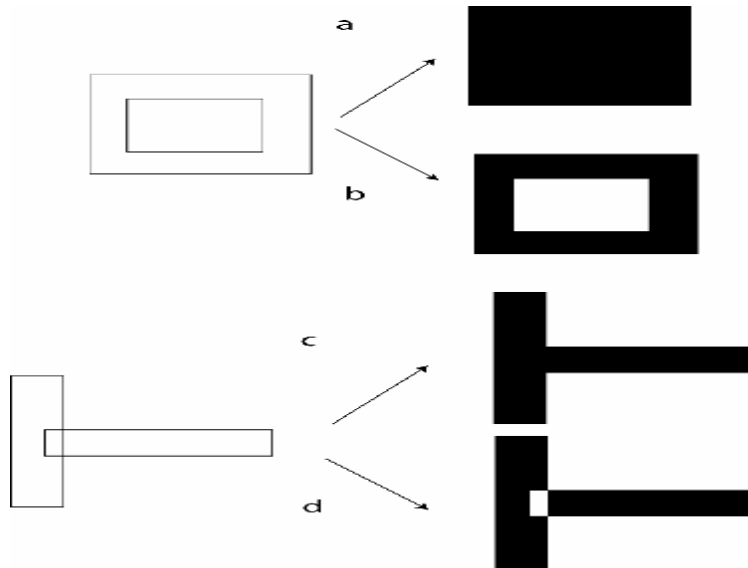

The software for printing that we use does b) and c) – but you need to confirm for your specific case. It is good practice to draw a border around the diagram. Let us make a boundary of 24000 micron x 24000 micron (fitting an inch square).We use a double-square to the correct hatching. Also, a good practice is to put identification marks on the chip. Find out what type of marks are allowed by your mask printing software. Finally, you might have (not to scale):

my first chip
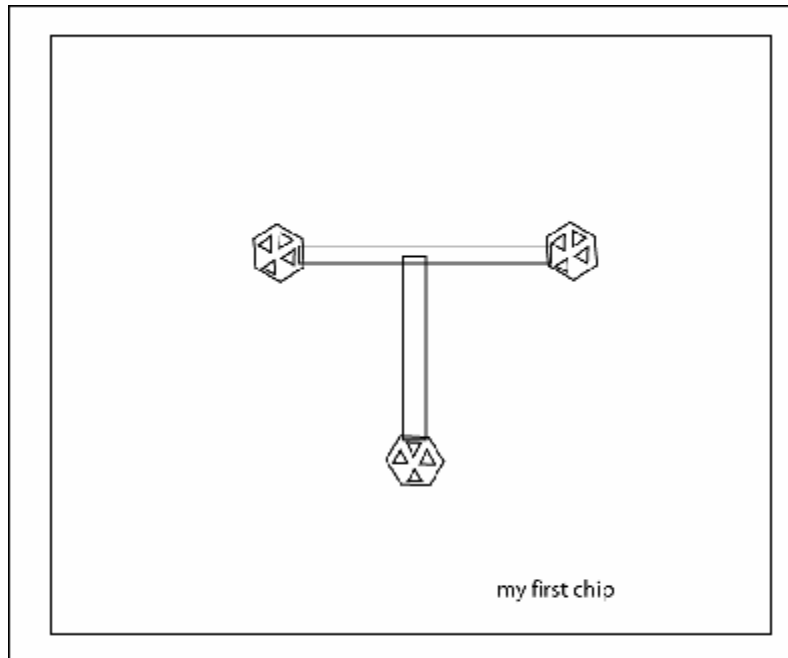
Note that because the lines are fairly thin, we will need to put some ports at the end of the line where hollow metal pins can poke through the PDMS and connect put fluids into and out of the chip. That is the larger structure at the end of each line. We put in some triangular posts to prevent collapse.

You will also have to decide whether this is to be printed negative or positive. If printed positive, it will be used with positive photo-resists, and if negative it will use a negative photo-resist. (Negative means that the channels you made will be transparent, and the rest will be dark like a negative of a photograph.) The photo-resist spinning speed during the molding determines the height of the channels, while the design determines the width and length of channels.

Now say you change your mind, and want to make a multilayer device with valves at the two inlet channels. A valve is created when two channels in different layers overlap (with one on top of the other), and a thin membrane separates them. This is done by molding either the fluidic or control channels in a thin sheet of PDMS, and then the other layer can be stacked on top of it.

Pin

Thick layer

Thin Layer

(~15 microns)

Glass
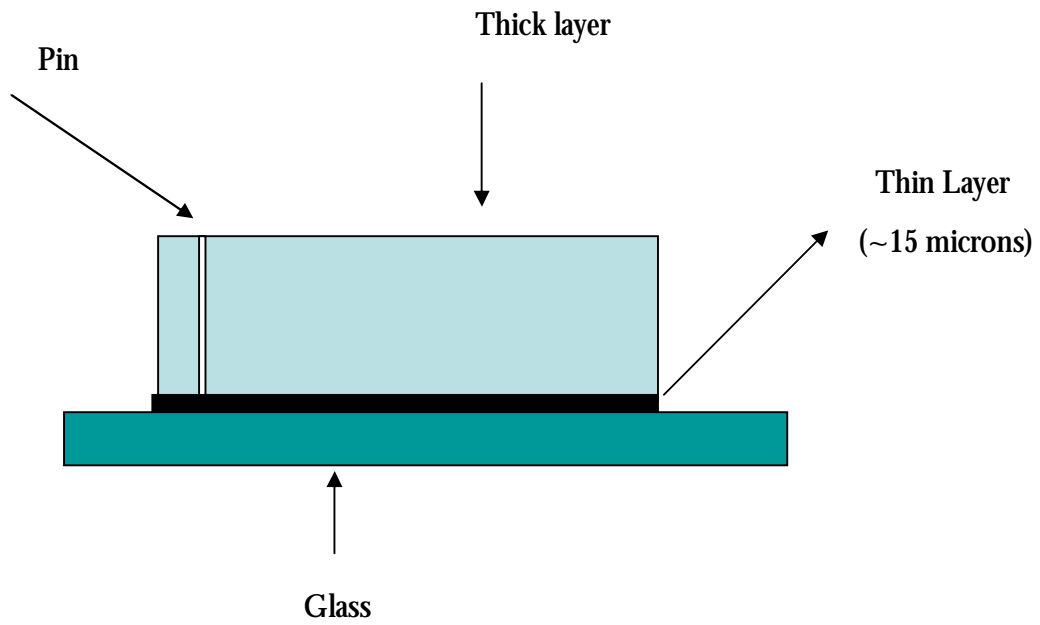
A new layer must be drawn on a separate layer – lets call this CONTROL and give it a new color. In AutoCAD it might look like this (not drawn to scale):

with valves tool

my first chip
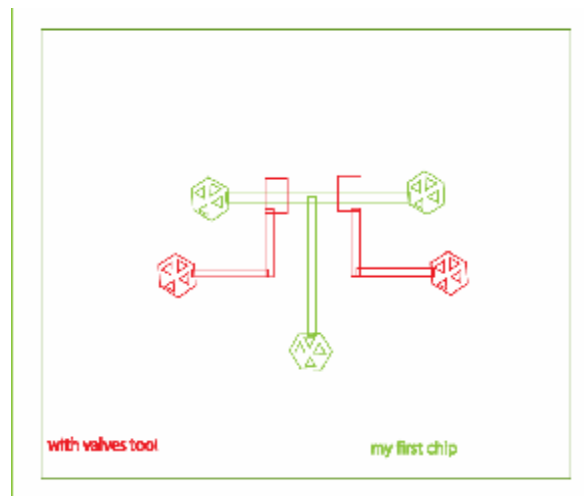
Note that with the control layer, we put a boundary (not seen in picture), ports, and identification marks. Also note how we increased the overlap area where we wanted a valve. This is a common strategy that helps lowering the actuation pressures.

It is essential that the ports be separated as far as possible from each other and other channels – at least 2 mm away from all other channels (except the one it connects to. of course!) and ports is a good rule of thumb. Since we need to poke pins into the ports and there is an element of error involved, this minimizes the chance of the pin rupturing another channel or port and ruining your device.

Finally, we need to separate the control and flow layers, make allowances for polymer shrinkage and arrange them to be put on a wafer. We use 3" silicon wafer so that 4 chips of the type drawn can fit into it.   So we can separate them as shown and put them on separate files. Here, we will plan to make the FLUID layer to be the thin layer. This is called the top-down geometry, because the valve functions by a thin membrane moving down. The other geometry is the bottom-up geometry, with the control channel below the flow channels.
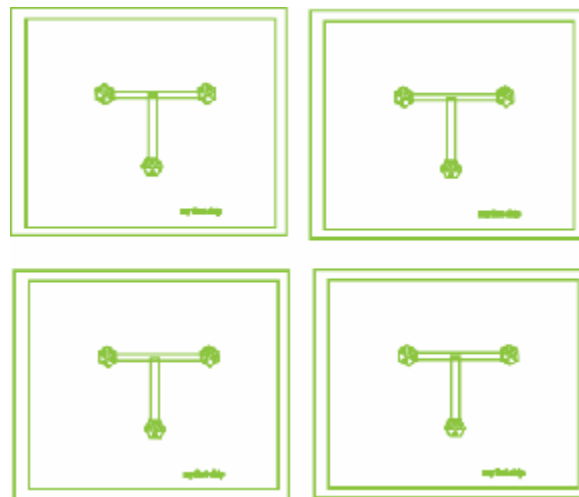
The thick layer must be EXPANDED by ~1.5 % to compensate for the shrinkage in the fabrication. Expand the control layer using the SCALE command by 1.015 and put it in the same format:
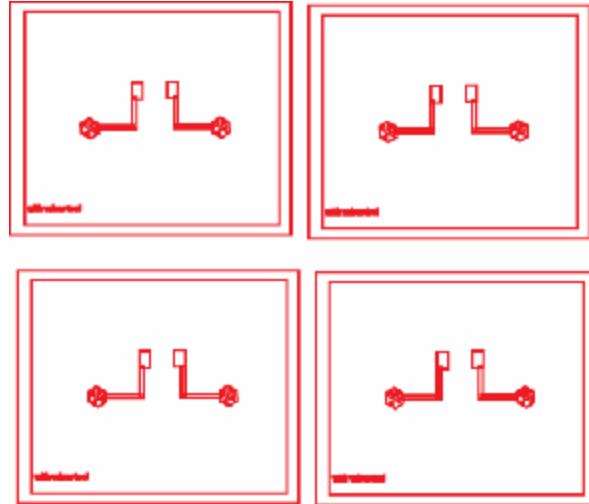
Normally, the flow channels are made with POSITIVE resists because we need to make them rounded, and this done by re-flow (square **à** parabolic) At present, we only know of positive resists that may be rounded. This is because a square cross-section will have its ends stick out when the valve action is done, preventing full closing of a valve (a leaky valve may be a good thing for cases where we want to just trap some large particles but allow flow through). The control channels may be printed negative.

At this stage you can simply hand your design to the *Caltech Microfluidic Foundry* (http://www.kni.caltech.edu/foundry) and they will make the chips for you!