BREATHE-IN

HARDWARE PROTOCOLS

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SU8 master fabrication (SU-8 2007, 10 µm features)

Notes:

- One master takes around 1 hour.
- This process is based on the MicroChem SU-8 2000 Data Sheet. Since the process information provided in the data sheet is aimed at high-throughput industrial production, for our work, it is only a starting point for developing our own process.

Cleaning glass slides

1. Clean the glass slide by using DI water, then squirt with ethanol, isopropanol and acetone.
2. Blow dry well with filtered gas.
3. Clean the glass slide by using acetone, isopropanol, ethanol, and DI water.
4. Blow dry well with filtered gas.
5. Dry on hot plate at 90˚C for at least 10 minutes.

Spin-coating SU8

1. For this procedure the user must wear, from the beginning, a lab coat and gloves.
2. While wearing safety UV goggles, turn on the DYMAX 400 Watt EC Power Supply in order to allow it to heat up for at least 30 minutes. The equipment will stay on until the end of the fabrication process (end of day) because if it is turned off the user will have to wait at least 40 minutes before turning on the equipment again. This is to allow it to cool down, since if the equipment is turned on while still hot, the life of the lamp will decrease drastically.
3. Place the SU-8 2007 on the hot plate at 90˚C for 10 minutes. This is to achieve the correct viscosity to be used with the Spinner and get the desired channel height. Note: To refill the flask with SU-8 the user must work under yellow light and with supervision.

Figure 1. Flask with SU-8 on a hot plate.

4. The process will be performed under yellow light. Turn on the Spinner pushing the button with a plastic cover in the back of the equipment, then open the main valve on top of the nitrogen cylinder and the small valve in the pressure regulator. Afterwards, turn on the vacuum pump connected to the equipment (Figures 2a and 2b).

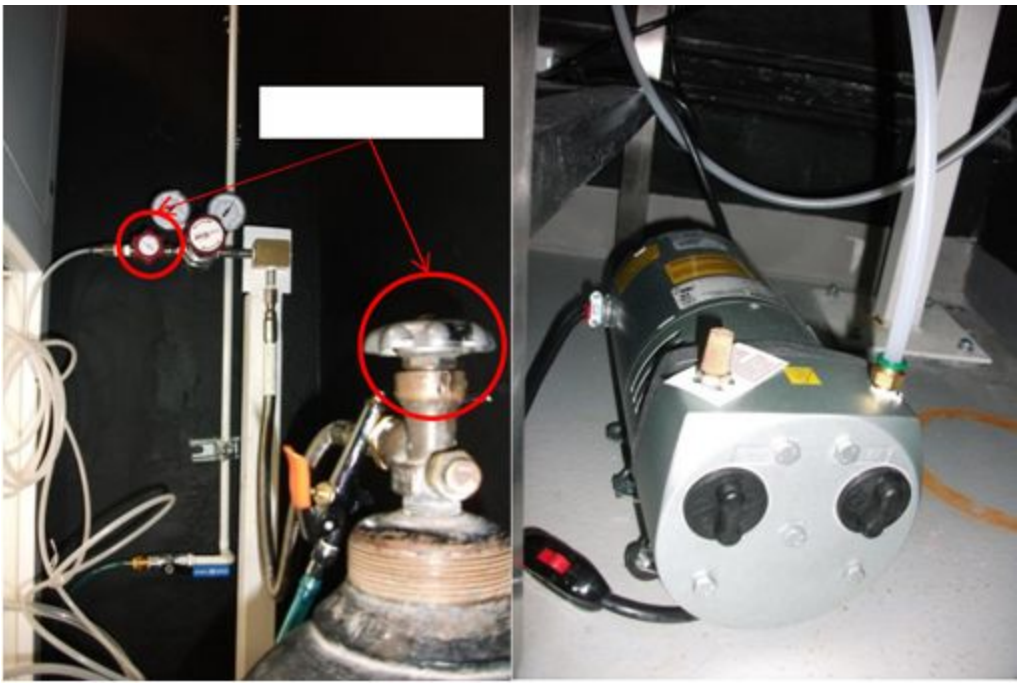

Figure 2. Main N2 valve (left), Vacuum pump (right).

5. Cover the inside of the Spinner with aluminum foil to aid in the cleaning after the spinning process.

6. Place the glass slide in the Spinner and apply “Vacuum” with the marked button.

7. Take the glass slide and apply a layer of SU-8 to cover most of the surface, starting from the center of the glass slide and being careful not to leave any bubbles in the surface. Gently move the glass slide to the sides in order to cover as much area as possible.

8. Using the center arrows select Program 4 on the Main Manu of the equipment and, if the display at the bottom shows the legend "Ready", "Start" the process. The equipment can show two error displays which will not allow to start the spinning process: 1) "Need CDA" means that there is not enough air flow (N2), check the valves mentioned on step 5 or that there is air pressure in the nitrogen tank; 2) "Need Vacuum" means there is not vacuum, check the vacuum pump.

Figure 3. Spinner (left) and Spinner display (right).

9. Once the spinning process is over, take the wafer out of the equipment chamber; release it by clicking on the button "Vacuum." If the user will no longer use the Spinner, the equipment can be turned off and the two nitrogen valves closed. If deficiencies are found in the SU-8 layer, try to see if the design can be placed so those do not affect the features. If it is not possible, then repeat the process. Note: to control the thickness of the SU-8 layer the user needs to verify the viscosity of the SU-8 and the spinning speed. Refer to the supplier datasheet to decide on the two parameters.

10. If you get a star shape of SU-8 on the glass slide, throw it away. If you get a bubble, do a long (1.5 to 2h) soft bake at 95˚C to make them go away (at this temperature the SU-8 starts to flow). Or pop the bubble using a small stream of acetone vapor near the bubble. You can generally ignore bubbles if you are not very bothered about the mask contact onto the wafer, though you might lose the features near the bubbles.

Soft bake

The soft bake is 2 min at 90˚C. Use a glass dish to cover the wafers during the soft bake, leaving a very small gap to allow solvent to escape very slowly and create saturated atmosphere above the wafer. This ensures that the upper side of the film does not dry out too much before the solvent at the bottom gets a chance to evaporate. The slower the soft bake, the better the quality of the film. Let the SU8 covered glass slide to cool down after the soft bake.

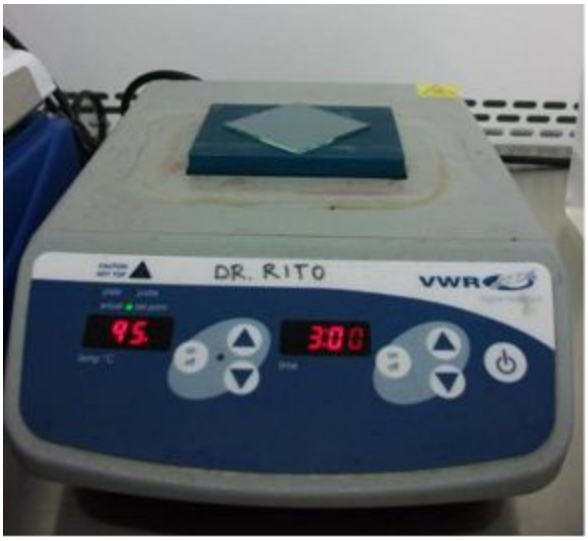

Figure 4. Glass slide example on the hot plate with controlled temperature.

Exposure

1. After the soft bake, take the mask with the desired design and place it on top of the glass slide with the SU-8. Place a clean glass slide on top of the mask and tight it up using black paper clips. Be sure that the front of the mask is directly placed in contact with the SU-8 layer (masks are usually mark with an “F” meaning “Front,”) that side must be in contact with the SU-8. This arrangement will prevent UV rays to inside in a different angle other than 90˚ and, therefore, deform the features on the final design.

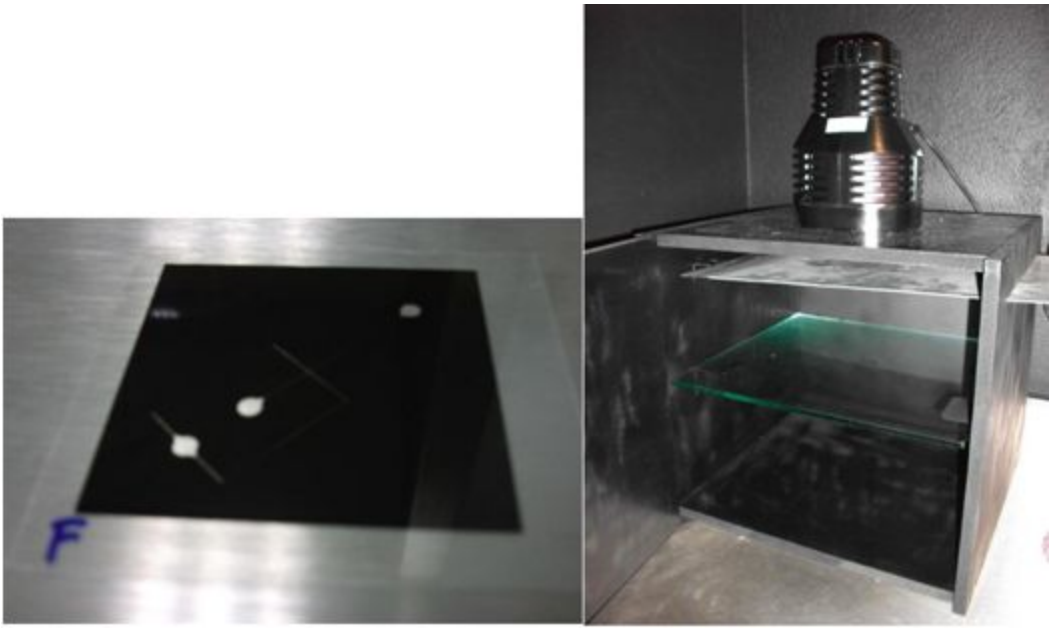

Figure 5. Mask marked with letter "F" (left), UV lamp chamber.(right)

2. UV exposure. Place the SU-8/mask arrangement inside the UV exposure chamber, taking care that it is horizontally levelled. Open the shutter for 7 seconds and close it immediately afterwards. Take the SU-8/mask arrangement out of the chamber after exposure.

Post-exposure bake

Post-exposure bake for a minimum of 4 min at 95˚C. For SU-8 2007 4 min is enough for all thicknesses. If your features are cracking, add an extra stress relief step for 2 minutes at 65˚C before increasing the temperature to 95˚C. The features should start to appear within a few minutes of starting this baking step but should not be visible before heating. Afterwards take it off the hot plate and let it cool down.

Developing

1. Use MicroChem SU-8 Developer and be sure that the extraction on the fume hood is on.
2. Allow a minimum of 5 min after turning off the hot plate for the wafer to cool to room temperature. This is important: not allowing enough time for cooling will cause thermal shock and cracking.
3. Pour developer into a glass container enough to cover the wafer, and then submerge the wafer for 3 minutes. Gently, rotate the glass container to improve developing.
4. Development time depends on shaking. You can't overdevelop by shaking, but some features might be lost if the time of developing is extensive. If you haven't developed fully, putting a drop of isopropanol on the wafer will create a precipitate, in which

case you will have to develop for longer. If the developer is loaded with SU-8 then you get the precipitate even is the wafer is well developed, so before putting isopropanol on the wafer, rinse the wafer with fresh developer. You can re-use the developer quite a bit, and you can check when it is saturated by adding isopropanol to the developer in a test tube to see if a precipitate is formed.

5. As a final step, rinse the glass slide with clean developing solution, then rinse with isopropanol and drip dry by standing the wafer carefully on its side. Do not use water to clean the wafer because it can leave debris on the surface. Once it has dripped dry, then dry with air gun. If you use air first, it can cause features on the wafer to crack. If you get cracking problems, then water rinse before isopropanol because it dries slower.

Hard bake

Ramp the wafer on the hotplate from room temperature to 125˚C and keep there for one hour. When cooling from the hard bake do it very slowly by turning off the hotplate and allowing the master to cool down to room temperature naturally.

Extra notes

· Be sure to clean up everything after the fabrication of the master was achieved. If the Spinner is dirty, clean it with some developer using the wash bottle, taking special care not to introduce any liquids in the center of the equipment (where the glass slide is placed). Be sure to turn off all equipment and close all valves. Leave the extraction of the fume hood on until no developer can be detected. Afterwards, turn off the extraction of the fume hood.

- For all films under 20 μm where the recommended bake time is less than 15 min, bake for at least 15 min. You cannot over-bake a wafer. Increasing the bake time really increases adhesion, so for 1 μm features for example, you need very long bake times. For thicker films, follow the recommended parameters, but on the long side. It is not uncommon to do hour long bakes for 50 μm film thicknesses.
- Spinning for longer times at lower speeds gives more uniform height distributions, so does soft baking at lower temperatures for longer periods.
- Underexposed SU-8 will not stick to the wafer, and overexposed features will be larger and rougher, and will have more aberrations. The minimum exposure dose that gives you adhesion is enough.
- Cracks on the wafer are due to thermal shock, so slow down the temperature changes.

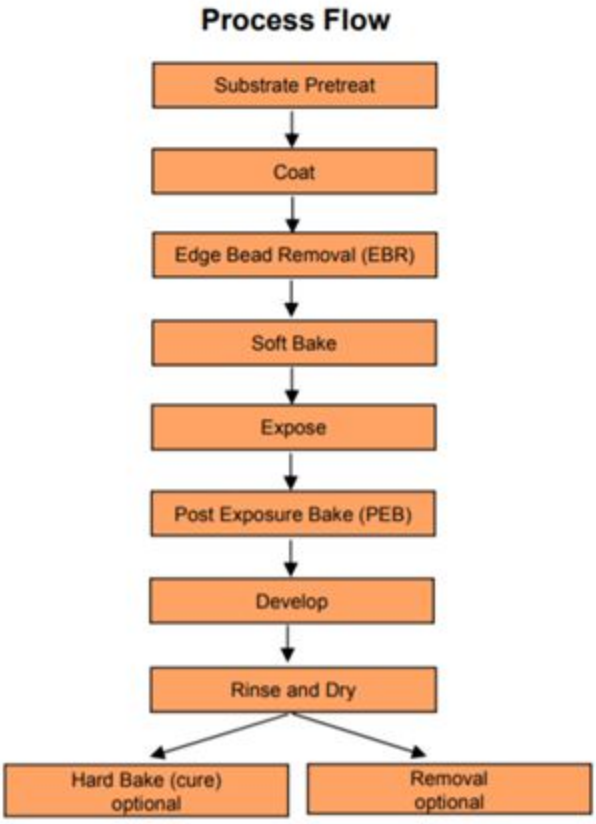

Figure 6. General process workflow

PDMS device fabrication

Casting PDMS

1. Create a mold with aluminum foil to hold your master. Make sure it lies flat and that there are no wrinkles under the master. Keep the foil tight to the master to prevent leaking.
2. Blow dust off the master carefully with a compressed air gun. Do the same for a small container to weigh the PDMS in.
3. Weigh the PDMS in a 10:1 base to curing agent ratio (10 g of base and 1 g of curing agent per master). Use only the scale located in the lab to do this and clean it well after use with ethanol.
4. Mix PDMS well with a spatula or mixing stick. The mixture will go slightly opaque and very bubbly when well mixed.
5. Pour the PDMS over the master.
6. Blow bubbles with an air gun to pop some of them and prevent PDMS overspill under vacuum.
7. Place wafer in a desiccator under vacuum, gently first, then full vacuum. Keep an eye on it for the first 10 minutes or so as the PDMS may overflow.
8. Leave until all bubbles have been removed (~30 minutes).
9. Put in an oven at 60˚C for a minimum of 2 hours or overnight (can use 65˚C or higher, but higher temperatures decrease the lifetime of the SU8 master).

Punching access holes

1. Carefully remove the foil from the master.
2. Gently pull off the PDMS from the master. Pull the PDMS slowly in the direction of the channel, at the shallowest angle possible.
3. Cover all channels with Scotch tape.
4. Cut out the individual PDMS devices with a box cutter.
5. Punch access holes using biopsy punches of the correct size for the tubing you will use (1/16 inch outer diameter).

Cleaning

1. Remove the Scotch tape from device.
2. Clean both glass slide and PDMS device by manually shaking in soapy reverse osmosis (RO) water with washing up liquid, cleaning well with DI water (ensure water squirts through access holes) and then squirt with isopropanol (squirt through the access holes so that they are clean) and ethanol. Put clean devices in basin with RO water.

3. Blow dry well with filtered gas, including through the access holes.
4. Dry on hotplate at 90˚C for 30 minutes.

Plasma bonding

1. Place both the PDMS replica and the clean glass slide in the plasma cleaner chamber. Make sure to have the channels in the PDMS replica facing upwards.
2. The glass slide and the PDMS to be bonded together should be place in front of each other, with the sides to be bonded facing up inside the chamber, at the back, a s it is shown in Figure 1.

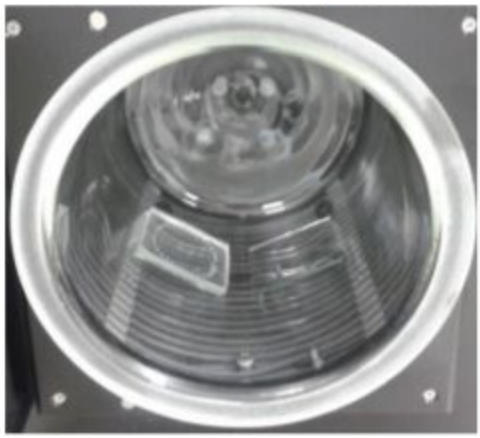

Figure 1. Glass and PDMS inside the Plasma Cleaner chamber

3. With the 3-way valve closed (vertical position as shown in Figure 2), turn on the vacuum using the switch "Vacuum Pump Power Switch" and leave the process for 3 minutes.

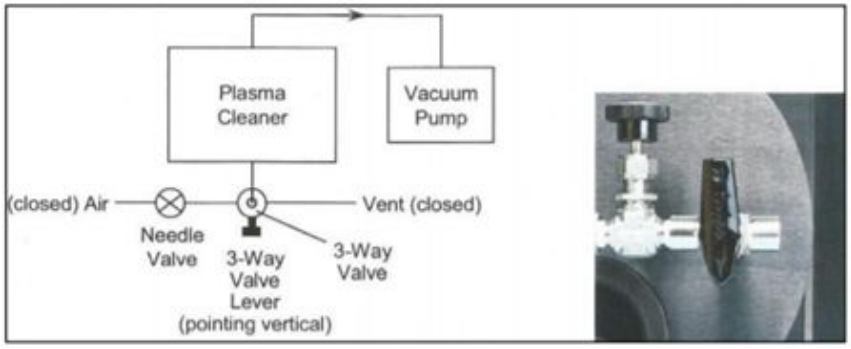

Figure 2. 3-Way Valve closed.

4. After 3 minutes, and still with the vacuum on, turn on the plasma with the switch "Plasma Cleaner Main Power Switch" and place the "RF Power Level Switch" in "HI" position.
5. Open the 3-way valve into horizontal position with the arrow pointing to the left, this to start the process allowing a small amount of air to come inside the chamber.

6. Carefully manipulate the “Needle Valve” if needed until the window show a bright pink plasma (Figure 15). Onced achieved, let the process last for 2 minutes.
7. After the 2 minutes turn the “RF Power Level Switch” into “OFF,” turn off the “Plasma Cleaner Main Power Switch,” and turn off the “Vacuum Pump Power Switch.”
8. Then, slowly turn the 3-way valve 180˚ so it stays in horizontal position but with the arrow pointing to the right. A sudden loss of vacuum could cause the inner contents of the chamber to move dangerously and the glass could break, that is the reason for doing this part slowly.
9. Take the glass slide and place it in a horizontal surface. Finally, place the PDMS on top with the channels facing down and gently press using a sharp object (such as tweezers) in the spaces between the channels to bond both surfaces. **Note**: Do not press directly into the channel or the bottom and top of the channel could bond together (collapse) which will make the device useless.