Photolithography (Includes LED Light Source Option)
By Mark Lum

1. Preparation, Setup, and Dehydration Process

A. UV Aligner  (Note: For LED Light Source, see Addendum and skip to Section B.)

Warm up the UV lamps approximately 30 minutes before actual use. The UV lamps will need the warm up time for the power to stabilize at the optimal level. If you need to understand the most recent UV power parameters, refer to the Log IN sheet where the UV Power has been recorded by previous users.

Note: If the UV Aligner has already been turned ON by a previous user, skip to section B.

When setting up OAI UV Aligner, refer to figures 1 and 2.

![Figure 1. Lamp Power Supply](image1)

![Figure 2. Aligner Control](image2)

Complete the following steps:

1. To setup the power, Flip the Power lever Up. This is shown in Figure 1. Almost immediately, the Lamp Current monitor will spike skewing to the right.

2. Hold down on the Start button for a few seconds. The needle will now skew to the left but after a few seconds slowly rise to the right slightly until it is between 0 and 5 amps. Once the needle moves to this location release the Start button.

3. Wait several seconds before turning on the aligner by flipping the Power switch up to the ON position. This is shown in Figure 2.

4. Allow a minimum of 30 minutes before using the UV aligner to expose a wafer.
B. Aluminum Foil Coverings for Hot Plates

Traditionally metal tweezers are used to transfer wafers in the Clean Room settings for Photolithography. While this is perfectly acceptable in handling wafers, there are a few drawbacks to using a tweezer. The first drawback would be imprint markings left behind in the location of where the tweezer secured the wafer. While this shouldn’t be a huge issue because the imprints would be at the edge of the wafer and most likely there wouldn’t be features in that particular region, it would only affect the appearance of the SU-8 mold.

It should be noted that imprint markings do not have any consequential effects on the functional use of the mold. The second drawback would be stability. Tweezers secure the wafer in one small region located at the edge of the wafer. Should the user lose their grip, the wafer may fall out from the tweezer. On the other hand, if the user exerts too much force when holding down the tweezer the wafer may crack.

One major benefit to using foil is that it catches excess resist that may slide underneath the wafer. Excessive resist could find its way on the reverse side of the wafer (non-polished side) once the spin coating is complete or when it is settling and hardening during the Soft Bake process. The use of foil would be convenient as the wafer would likely be stuck to it. If stuck, the wafer could easily be removed by pulling the foil away. This may not be the case if the wafer is stuck to a hot plate. Extracting it could be a little bit more difficult and with a possibility of breaking the wafer when removing it from the hot plate surface.

While these drawbacks aren’t significant if the user is careful, the alternative to using both foil and finger tips create a safer and secure approach to transport a wafer from one area in the clean room to another.

Figure 3. Hot plates used for baking wafers. Note the 3 hotplate settings and foil coverings
Note: If the aluminum roll in the cleanroom is empty contact staff immediately for a replacement.

1. Cut out three sheets of aluminum foil from the aluminum roll. For each Aluminum sheet, cut each slightly larger than the area size of the hot plate. The sheets of foil of will be used to transport the wafer from hot plate to another as well as carrying wafers to/from the spinner and UV Aligner.

2. Make sure the foil is completely flat against the hot plate surface. Creases or crinkles can prevent the wafer from making direct contact against the surface. This in turn could prevent the wafer from receiving proper heating temperatures during the baking or dehydration steps. Creases and crinkles may also cause the wafer to be un-leveled on the hot plate which can cause problems in the Soft Bake process. Be sure to place the foil on the surface before turning the plates on to avoid burns.

3. Cut out another foil piece that is slightly larger than the pieces of foils previously. This will be used to create a covering that will be placed directly over the hot plates during both the dehydration and baking steps. The foil will serve as a covering to prevent debris or particles from falling directly above while allowing air ventilation from the openings. See Figure 3 for visuals.

4. To form a foil covering, create walls using the edges of the foil piece. For each wall, fold the edge inward to form a crease. The folding crease should be approximately 1 inch from the edge of the foil.

5. Repeat the previous step again with the same side. This will give additional support to the wall structure. Form walls on two additional sides with the same piece of foil. Use the steps.

6. To properly create the corners for this foil cover, the corners of the foil piece will need to be tucked in. Tuck in the corners by folding the corner inward which will form a flap. Fold the flap to one side. Repeat this step again for the other corner.

7. Carefully shape the walls of the foil covering.

8. Place the foil covering over the hot plates.
C. Hot Plate Setup

See Figure 3 from the previous page as a visual for the setup for the hot plates:

1. Turn on three hot plates with the following temperatures: (1) 200 C (2) 65 C (3) 95 C. The 200 C hot plate will be used during the Dehydration step while the 65 C & 95 C will be used in the Soft, Post Exposure, and Hard Baking steps.

2. Use the IR Thermometer to read the actual temperature of each hot plate. Before making the measurements, remove the sheets of foil and coverings from the hot plates temporarily. Be sure to have the scanner set in Celsius (C) mode. There’s a button on the front of the scanner that can switch back and forth between Celsius (C) and Fahrenheit (F) units. Located on the back of the scanner will be another button. When this button is held down the scanner will take a temperature reading of its targeted surface indicated by the red laser beam projecting from it. Measure at the center of each hot plate when measuring the temperature. This will provide an accurate measurement reading as oppose to measuring at the edge of the plate. Make sure there is nothing on the hot plates at the time of measurement as it will throw off the reading. Once the measurements have been made place the sheets of foil and coverings back on the hot plates.

3. The readings indicated by the thermometer should be within a few degrees C to what is indicated on the hot plate monitor. Adjust the temperature knob if the scanner reads a temperature that shows a difference of 5 C or greater from what is indicated on the hot plate. Adjust the temperature knob until both the reading from the scanner and hot plate show roughly the same temperature.

D. Dehydration

The purpose of dehydration is to remove water from the silicon surface of the wafer. This is accomplished by baking the wafer at a high temperature. Before the wafer can be dehydrated it must be in a condition where it’s free from any kind of residues that could be present on the surface. Example of residues include: particles such as dust and debris, oils that originate from an organic source, and residual filmy substances from solvents. Any kind of residue that remains on the wafer could affect the adhesion of the resist to the wafer surface (silicon substrate) even with the use of an adhesion promoter. Residue could also lead to potential defects in the features that could affect the functionality of the finalized wafer (SU-8 Mold) later on.

The best way to clean the wafer from any existing residue would be to apply a combination of physical and chemical treatments to the silicon substrate. Physical treatment would involve a brush scrub with cleaning detergent to remove particles, oil, and substances present on the surface. Chemical treatment would involve applying acetone followed by isopropyl alcohol (IPA) to wash the surface. After both treatments, the wafer is then blown dried and prepped for dehydration. The cleaning process will be done inside the hood where beneath a hepa filter which is present to eliminate the dust particles in the air. The best place in the hood to clean the wafer would be near the common sink where both the de-ionized (DI) water and
nitrogen gas guns are easily accessed. In addition, usage of chemicals such as acetone and isopropyl alcohol must be done in the hood. This can be seen in Figure 4.

Figure 4. Solvent sink used for wafer cleaning.

Locate the following items for the cleaning process:

- Paint brush. This will be used to distribute the Alconox cleaning detergent over the silicon substrate.

- Alconox cleaning detergent (Clear bottle cap, the bottle will have Alconox written on it) Alconox is used to remove any existing debris, oils, particles, and residues which may be present on the wafer surface (polished side).

- Acetone (Red bottle cap with red labeling on the side). Acetone, a ketone, is used to help breakdown organic material and oils that may be present on the wafer surface.

- Isopropyl Alcohol (IPA) (Yellow bottle cap with yellow labeling on the side). Isopropyl, a secondary alcohol, is used in the cleaning process.

Complete the steps in the following order to properly clean the silicon wafer:

1. Shake the bottle containing the Alconox thoroughly before use. If the bottle is empty, make a new Alconox solution. Begin by removing the bottle cap and fill up the container distilled water until it’s nearly full. Add approximately 1 teaspoon of Alconox powder into the container. Shake the container thoroughly until the powder dissolves completely in the distilled water. Note: Ask staff for the carton of Alconox powder if it’s not present.

2. Wet the brush to soften the bristles.
3. Holding the wafer in one hand and the bottle in the other, apply a generous amount of Alconox over the wafer surface. While continuing to hold the wafer, gently brush the surface. Be careful not to exert too much force directly against the wafer as it will likely crack. The best way to brush the wafer would be in a circular motion. The hand that is holding the brush should move in a circular direction. Continue to brush until all areas of the wafer have been covered with Alconox. The backside of the wafer does not need to be brushed.

4. Rinse both sides of the wafer with distilled water. To effectively agitate the wafer, the hand holding the wafer should move in a circular motion.

5. Holding the wafer in one hand and the bottle in the other, apply acetone over the surface. Apply enough acetone as to cover all areas of the wafer. The backside of the wafer does not need acetone.

6. Holding the wafer in one hand and the bottle in the other, apply IPA over the surface. Apply enough IPA so that it covers all areas of the wafer. The backside of the wafer does not need IPA.

7. Rinse both sides of the wafer with distilled water using the same hand motions as described above. If there appears to be stains or residues left on the surface simply repeat the steps listed above.

8. Place a few clean white cloths in the area where the wafer will be dried.

9. Dry the wafer using the nitrogen gas gun located near the sink. The nitrogen gas gun will have black tubing. To effectively remove water from the wafer surface, swiftly apply hand motions that direct the N2 gun from the center to the edge of the wafer. By doing this the water droplets will be dragged from the center to the edges of the wafer.

10. At that point water droplets will either be pulled off from the wafer or remained clung to the edge. Water droplets that are clung to the edge can be removed by absorbing them to the white cloths when in contact. Continue to do so until the majority of the droplets have been removed from the surface.

11. Before drying the wafer any further, dry both hands thoroughly to prevent water from getting on to the wafer. When both hands are dried, continue to blow off any remaining water droplets that are still present on the surface.

12. Once dried, take a white cloth and wipe down the reverse side of the wafer.

13. Transport the wafer to the hot plate that is set for 200 C for the Dehydration step. Leave the wafer on the hot plate for a minimum of 15 minutes. Note: leaving the wafer to dehydrate longer won’t have any consequences.
14. After the Dehydration step is finished, carefully remove the wafer from the hot plate. Use the ends of the foil piece to lift the wafer off the plate.

15. Allow the wafer to cool to room temperature. Check the wafer periodically by placing one finger beneath the wafer. To help accelerate the cooling process, use the nitrogen gas gun to gently blow directly underneath the wafer.

II. Spin Coating

The purpose of the Spin Coating process is to apply a uniform coating of resist over the surface of the wafer. To improve the adhesion between the resist and silicon, an additional process is required to introduce a layer of adhesion promoter. Adhesion Promoters and photoresist will be briefly discussed in detail here.

Adhesion Promoter - Hexamethyl Disilizane (HDMS)

Before the photoresist can be dispensed, a thin film layer of adhesion promoter must also be dispensed over the surface. A common adhesion promoter used in the Spin Coating process is called Hexamethyl Disilizane commonly known as HDMS. HDMS improves the adhesion of photoresist to the silicon substrate by replacing the OH groups present on the silicon substrate surface with an organic group. The adhesion promoter can be thought as a coupling agent that chemically reacts to improve the adhesion between the organic surface (photoresist) and inorganic surface(silicon substrate).

The addition of adhesion layer will not guarantee the improvement of the photoresist adhering to the wafer surface. Other factors and conditions must be checked: the cleanliness of the wafer, dehydration quality, the cleanliness of the working environment and equipment.

SU-8 Photoresist

A photoresist is a solvent mixture comprised of solids and a solvent carrier (liquid). The protocols will focus on the epoxy-based SU-8 Negative Photoresist 2000 Series manufactured by Microchem. SU-8 photoresist consist of 8 epoxy groups. When the epoxy groups are cross-linked or polymerized they form a complete structure. The polymerization of groups will occur when the resist is exposed to UV light source which will happen later in the Photolithography process. The SU-8 2000 Series Photoresist comes in different viscosities hence the different numberings. The numbers correspond to a designated thickness height that the resist can achieve through the Spin Coating process. Each number or type of SU-8 resist will have a percentage of solids and solvent carriers present in the resist as well as both viscosity and density values. Resists that have a larger number will have a higher percentage of solids present in the resist, be more viscous, and have a greater density. Resists with a lower number will have a lower percentage of solids present in the resist, be less viscous, and have a lower density. The differences between the types of resists will be noticeable when dispensing over the wafer. Once the spinning is complete the surface will have a specific height thickness of resist. The actual height can be measured with a profilometer once the entire Photolithography process has been completed.
Important information that should be known before using any kind of resist is the expiration date. The expiration date should be listed on the labeling of the bottle along with the date that the resist was manufactured. For research purposes bottles that have already expired should not be used in the spin coating process. The reason for this is because expired bottles, depending on how long ago the bottle expired, may have solidity, viscosity, and density values that are different from what is officially listed on the Microchem Data Sheet. Solvent carriers from the solvent mixture are likely to evaporate from the bottle over time thus the solid concentration would be different. With this in mind there’s a very good chance that the actual thickness, after being measured with the Profilometer, won’t match the target thickness provided by the Microchem Data Sheet. In the case for both practicing and learning purposes expired photoresist would be fine to use.

A. Material Preparation

Gather and place the following items near the spinner machine:

- **Metal rack** - These can be used to hold wafers before and after the Spin Coating step. Particularly if extensive time is necessary for steps such as cleaning and last minute calculations.

- **Multiple clean white cloths** - These should be used to wipe down excessive resist and cleaning.

- **Plastic droppers** - These will be used to dispense less viscous SU-8 resists and adhesion promoter.

- **Q tips (Swabs)** - These will be used to wipe away excessive resist on the wafer edges after spinning.

- **Adhesion promoter bottle or decanted bottle.**

- **SU-8 Photoresist bottle or decanted bottle.**

- **Completed Spin Coating recipes.**

B. Equipment Overview

The equipment used to coat the substrate surface during the Spin Coating process is known as the spinner. The spinner contains a chuck, located in the middle of the chamber, which serves as the platform where wafers are placed during coating. In the center of the chuck, there is a small vacuum line that extends outward into the engraved channels that are present on the chuck surface. These channels create a uniform vacuum suction that hold the wafer in place as the chuck spins. The spinner contains a hatch lid located at the top of the spinner. The hatch protects both the chuck and chamber as well as keeps resist contained within the chamber for
excessive amounts will fly off the wafer during the spin. Also located at the top of the spinner, there is a metal alignment structure which is used to center wafers over the chuck. To operate this alignment structure simply lower it and push the two metal pegs forward. Wafers must be properly centered before spinning to ensure that both resist and adhesion promoter can be uniformly distributed over the surface. To center over the chuck, simply position the wafer so that it’s making direct contact to the two metal pegs. Once centered, the alignment structure can be raised up and returned to its original position. To reduce the amount of resist from accumulating on both the walls of the chamber and hatch, foil is placed over the surfaces. The foil is to be discarded and replaced once the Spin Coating process is complete.

C. Inspecting and Cleaning Equipment

Before cleaning, check the pressure gauge located directly underneath the spinner table. The needle inside the gauge must be between the range indicated by the red markings. If the needle isn’t within range, do not proceed any further in setup. Notify staff member immediately.

Lift open the hatch. Check to see if there’s any residual resist present on the spinner chuck platform (SU-8 negative photoresist, 1800 AZ positive resist) or PDMS material. Any kind of residual resist or PDMS that is laying on the surface of the chuck or in the channels of the air pathways will result in poor vacuum. The ‘Poor Vacuum’ sign would be indicated if a wafer is placed on a dirty chuck and programmed to spin. Debris on the surface would create a separation gap between the chuck and wafer. A separation gap would prevent a vacuum suction between the two surfaces. If there’s resist or PDMS present in the channels, it will create a blockage that would prevent vacuum suction in those affected areas. If resist or PDMS is present on the surface or in the channels, proceed to cleaning.

Complete the following steps to clean the spinner:

1. Apply a generous amount of acetone to a clean cloth wipe.

2. Wipe down the surface of the chuck inside the spinner.

3. Using a razor carefully scrape off any residual resist that is trapped in the air pathway channels of the spinner platform. Only scrape in the channels of the chuck. Careful not to scratch the platform. As resist fragments begin to accumulate on the surface while scraping, use a nitrogen gas gun to blow them off the chuck. Use the gun to spray resist fragments in an outward direction, away from the chuck. Avoid getting resist fragments in the vacuum opening located in the center of the chuck. If the opening gets clogged, it will prevent a vacuum suction from occurring. Should this happen, notify staff immediately!

4. Wipe down the chuck again with a clean cloth wipe soaked with acetone.

5. Dry the chuck with the nitrogen gas gun.
D. Programming Equipment

Located to the right of the spinner is a panel. The panel will be used to manually program a Spin Coating recipe that is stored in the machine memory. The programming is designed in steps. Each step contains the following: Dispense option, velocity (RPM) value, acceleration (R/S) value, Step Nozzle option, and time (S) value. Only the velocity, acceleration and time values need to be programmed for each step. Steps are to be programmed in pairs of two. In each pair, one step serves to dispense either the Adhesion Promoter or resist over the entire substrate surface while the second step serves to achieve a desired thickness. Together both steps will represent one part of a two part Spin Coating process. The first part of the program is designed to dispense the Adhesion Promoter or resist over the entire area of the wafer. The second part of the program is designed to spin the wafer both fast and long enough to achieve an optimal height. Combined, the Spin Coating process will have four total steps. For all steps, the Dispense and Step Nozzle are not important to the Spin Coated recipe and should be skipped over when the step appears in the panel screen.

Provided below are short descriptions and breakdowns of each of the following steps used in the Spin Coating process:

Dispensing Step(s) -

The dispensing step, for either resist or Adhesion Promoter, will have fixed values for velocity, acceleration, and time. The velocity value to dispense resist or adhesion over the entire surface substrate will be fixed at a value of (500 RPM). When dispensing resist or adhesion promoter over the entire substrate surface, an acceleration value of (100 R/S) will be used. The time duration for the step will be fixed at (10 S).

Adhesion Promoter Spinning Step

For the Adhesion promoter, the optimal height velocity value should be a value that is high enough to achieve a thin coating. There is no specific velocity value for this step. A velocity value between the range of (2000 RPM) and (3000 RPM) should be sufficient for coating. The acceleration value, regardless of what velocity value was entered should be fixed at (300 R/S). Similar to velocity, there’s no specific time value for this step. A time value between (20 S) and (30 S) should be sufficient.

Photoresist Spinning Step

For the photoresist, the optimal height velocity is determined by looking at the Microchem Data Sheet for specific velocity value that corresponds to a specific thickness. When the wafer is being spun for a specific thickness, regardless of what velocity value was entered, a fixed acceleration value of (300 R/S) will be used. The time value will consist of the difference of the velocity divided by the acceleration. The difference of the velocity is determined by taking the Terminal velocity and subtracting it from the optimal height value determined previously. The Terminal velocity has a constant value of (500 RPM). The acceleration value will have a constant value of (300 R/S).
Programming and Flow Chart

The programming process has an order of options to be entered:

Dispense Setup → Velocity Value → Acceleration Value → Nozzle Setup → Time Value

Note: Once the values and options have been filled, the programming will proceed to the next step, if applicable, using the exact same order for options to be entered.

Important: If numerical ‘0’ button on the spinner does not work! In the event that a ‘0’ value must be entered as a digit for some number, use the values of either ‘1’ or ‘9’ instead. This will also apply when an option requires use of the ‘0’ value to execute some kind of command. An example of this will be when the option to repeat a Test Spin appears on the monitor screen. For this example simply press the command RESET which will return the spinner in its ‘stand by’ mode. Repeat the execution of the program by pressing the command RUN followed by the numerical value. The Test Spin will repeat itself again.

Follow the steps below and steps shown in the table below to complete the programming:

1. Turn On the machine by repressing red ON/OFF (1/0) button located to the left of the programming pad.
2. Press the button ‘PROG’ to begin programming the spinner
3. Enter a numerical value to save the recipe into the machine.
4. Complete the steps in order listed in the Flow Chart below. Note: The program setup covers the two steps for ONLY one part of the Spin Coating process described above. The programming setup will need to be completed again for the second part. Depending if both the Adhesion Promoter and SU-8 Photoresist recipes are intended to be stored under the same or different numbers, the programming setup may need to be programmed again following the completion of the first part.

Flow Chart

<table>
<thead>
<tr>
<th>Programming Order</th>
<th>Commands</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROG MODE/PROG#</td>
<td>Enter a numerical value (1-9), Press ENTER</td>
<td>Identity of program recipe</td>
</tr>
<tr>
<td>DISPENSE 1=ON 0=OFF</td>
<td>Press ENTER</td>
<td>No numerical value needed</td>
</tr>
<tr>
<td>PG/(#) VEL/0</td>
<td>Enter a numerical value for velocity. Press ENTER</td>
<td>If the numerical value cannot have a ‘0’. Either use a ‘1’ or ‘9’ in place of a 0.</td>
</tr>
</tbody>
</table>
### Instructions:

**Complete the following to setup the wafer for a Test Spin:**

1. **Run the entered program.** Press the button ‘RUN’ to begin the program.

2. **Enter in the designated program number** that was programmed for spin. Press ENTER.

3. **Carefully load the wafer over the spin platform**

4. **Carefully pull down the wafer aligner located in the corner to properly center** the wafer of the platform.

5. **Once the wafer has been centered properly, proceed to running the Test Spin by pressing the START button.** If the test spin was successful, proceed to the next step. If the test spin wasn’t successful, which would be indicated by an ‘ERROR POOR VACUUM’ sign, the spinning platform must be cleaned again. Redo steps by entering in the numerical value then proceed to running another test spin.

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<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG/(#) RMP/0</td>
<td>Enter a numerical value for acceleration. Press ENTER</td>
<td>If the numerical value cannot have a ‘0’. Either use a ‘1’ or ‘9’ in place of a 0.</td>
</tr>
<tr>
<td>PG/(#) STEP-0 NOZZLE#1</td>
<td>Press ENTER</td>
<td>No numerical value needed</td>
</tr>
<tr>
<td>PG/(#) TIME/0</td>
<td>Enter a numerical value for time. Press ENTER</td>
<td>If the numerical value cannot have a ‘0’. Either use a ‘1’ or ‘9’ in place of a 0.</td>
</tr>
<tr>
<td>PG/(#) VEL/1</td>
<td>Enter a numerical value for velocity. Press ENTER</td>
<td>If the numerical value cannot have a ‘0’. Either use a ‘1’ or ‘9’ in place of a 0.</td>
</tr>
<tr>
<td>PG/(#) RMP/1</td>
<td>Enter a numerical value for acceleration. Press ENTER</td>
<td>If the numerical value cannot have a ‘0’. Either use a ‘1’ or ‘9’ in place of a 0.</td>
</tr>
<tr>
<td>PG/(#) STEP-1 NOZZLE#1</td>
<td>Enter a numerical value for acceleration. Press ENTER</td>
<td>No numerical value needed</td>
</tr>
<tr>
<td>PG/(#) TIME/1</td>
<td>Enter a numerical value for time. Press ENTER</td>
<td>If the numerical value cannot have a ‘0’. Either use a ‘1’ or ‘9’ in place of a 0.</td>
</tr>
<tr>
<td>PG/(#) VEL/2</td>
<td>Press ENTER</td>
<td>Ends the program</td>
</tr>
</tbody>
</table>
E. Coating Setup and Running Program

Using Decant Container(s):

To minimize the chance of spills and contamination, a smaller decant container should be used when dispensing adhesion promoter or resist directly over the silicon substrate. Ahead of time, aliquot the resist from the Microchem SU-8 bottles into a new decant container. Bubbles will tend to form when pouring; therefore pouring in advance is a good idea. To reduce the amount of bubbles in the resist, tip the decant bottle slightly when pouring. Allow time for bubbles to surface from resist before use. If there are no existing decant containers that are filled with adhesion promoter Hexamethyl Disilizane(HDMS), aliquot this into a new decant container. When ready proceed to pouring.

Adhesion Promoter Coating

1. Open the container. Hold the container with one hand and pipette up a few drops of adhesion promoter with a dropper. Without making direct contact to the wafer, place the dropper at the center and release adhesion promoter. The liquid dispersed on the silicon substrate should be the approximate size of a quarter or about an inch in diameter.

2. Close the hatch.

3. Run Program by pressing START. Wait for the program to finish before continuing.

SU-8 Photoresist Coating

1. Reprogram the spinner for SU-8 Photoresist portion of Spin Coating process ONLY if the same programming number was used for storing the adhesion promoter recipe and running the program.

2. For SU-8 photoresist, depending on the viscosity (solidity of the resist), the resist can be applied by either a dropper or directly from the decant bottle. The lower end of the 2000 series (2000.5, 2002, 2005, and 2007) has a low viscosity and therefore a dropper should be used. In the exact same manner as the adhesion promoter, described previously, apply the resist directly over the silicon substrate. Continue to apply resist until at least 75% of the total surface is covered with resist. For the resists with a higher viscosity (2010, 2015, 2025, 2035, 2050, 2075), pour directly from the bottle. Apply resist until at least 50% of the total surface is covered with resist. With a clean cloth, wipe the edge of the decant bottle as to remove any excessive resist along the rims that may be present. Once the resist dries it will make unscrewing the bottle difficult.

3. Check the surface of wafer for any air bubbles that may be present when applying resist. Bubbles can be removed in one of three ways. The first way would be to pop them directly. Take a thin syringe needle or pipette tip and poke at the exact location of the bubble. The second way would be to suction up the bubble with a dropper. Place the tip of the dropper at the exact location of the bubble. The third way would be to drag the
bubble either to the edge or off the wafer. Use a syringe or pipette tip to drag the bubbles. Avoid dragging resist beneath the wafer when using this approach.

4. Close the hatch. Run Program by pressing START. Wait for the program to finish before continuing.

5. Open the Spinner lid.

6. Before pressing RESET to return the spinner back to its ‘stand by’ mode which will also release the vacuum suction between the spinner platform and wafer, the edges of the wafer must be cleaned. Using the wooden portion of the q tip carefully around the edges of the wafer to remove excessive resist. Once the edges have been wiped, press RESET to release the wafer.

7. Carefully place fingers of both hands underneath the wafer and lift. Transport the resist covered wafer to the 65 C hot plate. While transporting, be sure to keep the wafer leveled. It’s possible for the resist to shift slightly which would result in uneven levels of heights later on if it’s not properly leveled.

**Clean Up**

1. If no additional layers of resist or no additional wafers need to be coated, replace the foil inside the spinner. To remove the foil from the spinner, carefully lift both the metal rim and plastic holder over the chuck and then carry away from the spinner. Clean up any resist spills that may occur once the holder and rims are removed. Remove and discard the foil into trash.

2. Cut out a piece of new foil that is large enough to cover the entire plastic platform. Place the foil directly over the platform.

3. Place the metal rim over the foiled cover plastic.

4. Fold all foil edges forward to cover most if not all of the metal rim.

5. Once covered, create a hole in the center of the foil large enough so that the chuck could fit through.

6. Carefully place the foil covered rim and platform back into the spinner. Place directly over the hole opening so that the chuck could go through.

7. Close the lid.

8. Turn off the spinner.
III. Pre Exposure Bake (Soft Bake)

The purpose of the Soft Bake process is to dry out the resist by removing any remaining solvent carriers that are present in the resist coating the substrate surface of the wafer. Prior to baking, the resist has not solidified and therefore is not stable. In the event that a wafer was not placed on a leveled surface the resist could skew over to one side of a wafer. This will result in a non-uniform layer of resist which can have consequential effects to PDMS mold making (Soft Lithography). Removing the solvent carriers is necessary to ensure stability of the resist. Solvent carriers may be removed through evaporation if a wafer is allowed to sit out without being placed on a hot plate. The removal of solvent carriers by evaporation will result in a change of resist properties and therefore it is not necessary for the wafer to undergo a Soft Bake prior to UV Exposure. In the Soft Bake process, the wafer will notice: a reduced thickness of resist from the removal of solvent carriers, stronger adhesion between resist to silicon substrate, and a change in texture from initially being sticky to non-sticky and solid.

Complete the following steps:

1. Carefully place the resist covered wafer on the 65 C foil covered hot plate for an appropriate time.

2. Once the appropriate time has passed, carefully lift the foil from the hot plate and place it over the 95 C hot plate. Allow the wafer to sit on the 95 C hot plate for an appropriate time.

3. Remove wafer from hot plate. Allow the wafer to cool to room temperature.

IV. UV Exposure (Note: If using LED Light Source, see Addendum)

The purpose is to expose an Ultra Violet (UV) light source against the photoresist which would change the solubility (polymerization). UV lighting with an i-line has a wavelength of 365nm. With this specific wavelength, which is a requirement for SU-8 photoresist, polymerization of the photoresist can occur. For negative resists the photoresist film becomes insoluble when exposed to UV. Mentioned previously, SU-8 photoresist is composed of 8 long molecular epoxy group chains. Exposure to UV lighting will cause a cross-linking process of the epoxy group chains forming a final structure. The opposite will occur with positive resists with resist becoming soluble when exposed to UV. To separate out which portions of the resist on the surface substrate will be exposed to UV, a Photomask (Mask) is used to block out light in areas specific to a feature.

There are two common types of masks used in lithography: Mylar mask and Chrome mask. Mylar masks are transparency masks that are printed by laser printing. They are inexpensive, quick turnaround in production, and can offer high resolution features (no lower than 8 microns). Chrome masks are masks comprised of a glass (or quartz) plate with printed chrome by the method of either laser writing or a higher resolution masking process. The Chrome masks are both more expensive and time consuming to produce.
Masks that are designed for negative resists will have the inverse image or negative pattern that is to be transferred to the wafer which will later form a positive pattern on the silicon substrate surface. Masks that are designed for a negative photoresist will have features uncovered for exposure. Features will experience cross-linking of epoxy groups thus become insoluble while any remaining areas covered by the print from the mask, won’t experience crosslinking. The crosslinked areas will remain intact inside the developer while non-crosslinked areas will wash away from the substrate surface.

The setup for exposure uses a Contact Printing approach in which the printed mask is pressed directly against the resist covered wafer. Light emitted from the aligner will aim directly at the mask, exposing through either the Mylar film or chrome glass areas that are not covered.

An important property to know about the UV Exposure process is the Standing Wave effect. Standing Waves are caused when light is emitted from the lamp directly through the resist and against the wafer then reflected back. As light waves are being emitted directly at the wafer and reflected back simultaneously, they create an interference patterns consisting of different depths of high and low light intensities. The variation of these light intensities will create shaped ridge patterns (ripples) along the interface between the soluble and insoluble regions in the resist. After development, these ridge patterns will become noticeable on the sides of features if observed under a microscope. The patterns caused by the waves can be corrected and reduced to a minimum through the Post Exposure Bake process.

A. Exposure Calculations

Determine Exposure Energy Dosage and Power Intensity

Two important factors are required to determine the exposure time: the Exposure Energy Dosage and the Power Intensity of the UV lighting. The dosage of energy exposure will depend on the targeted thickness of the resist. Refer to the MicroChem data tables for this variable that corresponds to a specific thickness. The Intensity of the UV Lighting can be determined by using a power meter. Use the OAI power intensity meter, located by the power box, to determine power of the UV.

Complete the following steps to measure the Power Intensity value:

1. Set the aligner timer for a quick exposure. A short exposure time of approximately 5 seconds would be enough time for the power intensity meter to give an accurate intensity value.

2. Place the sensor that is connected to the meter via cable over the center of the glass plate. Make sure the correct side of the sensor is facing up. The correct side will have a small white circle (sensor area) in the middle of the center.

3. While holding the handle and pressing the button in front simultaneously, carefully drag the aligner stage directly under the UV lamp. Once directly underneath, the UV lamp will turn on.
4. Make note of the power as indicated by the meter.

5. Wait until the UV lamp times off.

6. Holding the handle and pressing the button simultaneously, carefully drag the aligner stage away from the UV lamp back to its original position.

**Optimal Exposure Time & Scaling**

Knowing the values of both the Energy Dosage and the Power Intensity variables, the Exposure Time can be determined. Take the determined Exposure Energy Dosage and divide by the Power Intensity value to determine Exposure Time. Depending on the targeted thickness of the resist, the Exposure Time may need to be scaled. The Exposure Time can be scaled by multiplying the value by a certain percentage.

\[
\text{Exposure Time} = \frac{\text{Exposure Energy Dosage}}{\text{Power Intensity}} \times \text{Scaling Percentage} \%
\]

This percentage is determined by determining at what optimal point the resist will receive thorough exposure. Below this optimal point will likely result in underexposure which will cause the resist to be partially exposed thus partially insoluble. Exposure will begin at the top of the resist layer working its way to the bottom. Consequently, this will result in a “Lift Off” effect, or resist coming off the wafer after development because the layer was partially insoluble, polymerizing at the top but not the bottom. On the other hand, above the optimal point will result in overexposure of the resist. At a certain point, once the UV has penetrated all unmasked areas, the lighting will begin to travel laterally. In a lateral direction the UV will begin to polymerize resist that is covered by the mask. Consequently, this will result in features not coming out later in the Development process. This will be especially true for very fine features.

To determine the correct Scaling Percentage, users must characterize their Exposure Times. Through characterization an optimal Scaling Percentage can be determined based on what is seen under a microscope. The process of characterization involves trials using different Exposure Times with each trial being slightly different in its exposure. The best way to do this would be to have Exposure Times that are different incrementally. For example a characterization process could involve increasing incrementally by 25% for each sequential trial. After analyzing the trials, one of them will likely show better development resolution than the others. The one that shows the best resolution after development would represent the optimal Exposure Time. Keep in mind the optimal Exposure Time will be different depending on both the thickness and design of the features that is to be implemented on the wafer.
B. Cleaning and Mask Loading

Refer to the following steps below to clean and load either a Chrome plated mask or a plain glass plate for a Mylar Mask. Begin at Step #1 for a plain glass plate with a Mylar mask. Begin at Step #6 for a plated Chrome Mask.

1. Remove the glass plate from the aligner.

2. Carefully unscrew the two screws located on the front side of the aligner. Do not attempt to unscrew the screw on the back side of the aligner. The screw in the back is fixed in place.

3. Carefully lift up the alignment holder that holds the glass plate.

4. Remove the screws and frames that keep the glass plate in place. Turn OFF the Mask Vacuum if it’s On.

5. Remove the glass plate from the aligner.

6. Inspect the cleanliness of the plate. If it appears dirty (residual resist, debris, oils, smudges, etc) then the plate will need to be thoroughly cleaned.

7. To clean the plate, apply Alconox detergent to both sides of the plate. Using a brush thoroughly clean each side. Clean the plate the exact same way as if cleaning a wafer which was described in the Preparation, Setup, and Dehydration Section. Rinse the plate off with the Di water. Apply acetone to each side of the plate. Apply IPA to each side of the plate. Rinse the plate off with the Di water. Dry each side of the plate with the nitrogen gas gun.

8. Carefully place the glass plate or Chrome Mask back into the alignment holder. For the Chrome Mask, be sure that the feature (pattern) side is facing downward so that it will make contact against the silicon substrate. The Chrome Mask will be facing upward if the alignment holder is flipped upside down.

9. Carefully place the frames and screws back in its place. Turn On the Mask Vacuum.

10. Flip over the alignment holder and carefully place it back into the aligner. Re-tighten the screws in the front.

11. If using a Mylar mask proceed to the following steps.

Refer to the following steps below to clean and load a Mylar mask:

1. If the mask has never been used, trim the mask such that it’s approximately the same size as the glass plate or a specific shape or size that’s required.
2. Identify which side of the mask contains the printed features. This should be done under lighting. To determine the printed side, use a razor or syringe needle to scratch the surface of the mask preferably on the extreme edges of the mask. The print will easily come off when scratched. The printed side of the mask is the side that will be facing against the wafer. The non-printed will be bonded to the glass plate.

3. To bond the mask to the glass plate, apply a minimum amount of water to each of the corners of the non-printed side of the mask. A single drop of water is more than sufficient for all four corners.

4. Remove the screws and frames from the glass plate. Carefully remove the glass plate from the alignment holder for Mylar Mask bonding.

5. Once all four corners have a minimum amount of water, carefully align the mask surface against the glass plate. Once aligned, firmly press down on the corners to ensure adequate bonding between the glass and mask. Wipe off any excessive water if present.

6. Carefully place the mask back into the alignment holder. Be sure that the printed side is facing downward so that it will make contact against the silicon substrate. The Mylar Mask will be facing upward if the alignment holder is flipped upside down.

7. Carefully place the frame and screws back in its place.

8. Turn On the Mask Vacuum.

9. Flip over the alignment holder and carefully place it back into the aligner. Re-screw and tighten the screws in the front.

C. UV Aligner Setup:

Cleaning Chuck

Before placing the wafer onto the chuck platform, you must inspect for any residual resist or debris on the chuck surface. Resist or debris can prevent the wafer from making full direct contact against the chuck platform. This is observed when a slight separation gap between the mask and wafer is present. Consequently, a separation gap will affect how strongly the wafer is held to the chuck by use of a vacuum (Substrate Vacuum). A wafer that is not secured to the chuck can easily become displaced, throwing off precision during alignment.

Another problem that could occur when residual resist or debris is present on the chuck surface is that it can cause the wafer to be tilted or slightly unleveled. A wafer that is unleveled may experience improper UV exposure. When this occurs, a portion of the wafer will be making full contact against the mask while another portion won’t be making full contact. Consequently, the portion of the wafer that isn’t making full contact will experience UV exposure leaking beneath the mask. This could affect the shapes of the features on the silicon substrate. The mask can only properly cover the resist from exposure if the wafer is leveled.
Complete the following steps to clean the chuck platform surface:

1. Check the chuck platform surface for any residual resist or debris that may be present on the surface. If there’s any residue present, carefully scrape the surface using a razor. Be extremely careful not to scratch the chuck surface.

2. Check to make sure that the vacuum passageway channels embedded in the chuck is free from any residual resist. If there’s any resist present carefully scrape off the residue with a razor. Be extremely careful not to scratch the channels. To properly clean the channels hold the razor at a 45 degree angle and gently scrape along the embeddings.

3. Wipe down the chuck with white cloth with some acetone. Use a nitrogen gas gun to dry the chuck surface.

4. Proceed to loading the wafer into the aligner.

**Loading Blank Wafer on the Chuck**

A blank wafer will be inserted into the aligner. This blank wafer will act as a proxy to the actual wafer undergoing UV Exposure. Once the wafer is loaded onto the chuck, it can both be properly positioned and leveled against the mask. After the chuck has been configured the blank wafer can be switched out with the actual wafer.

1. Locate a clean blank wafer.

2. Open the Mask Frame of the aligner by flipping the ON/OFF switch up.

3. Check to see if the chuck platform is completely lowered. To raise or lower the chuck, adjust the Z-axis knob.

4. Once it has been lowered place the wafer directly onto the chuck. Center the wafer over the chuck as much as possible. Check to see if the wafer is completely leveled on the chuck. Check for any separation gaps.

5. Once aligned turn on the Substrate Vacuum switch ON. The Substrate Vacuum will create a suction that will hold the wafer in place from beneath.

6. Close the Mask Frame of the aligner by flipping ON/OFF switch down.

**Position Blank Wafer and Chuck**

Located on the front and sides of the aligner are the axis and rotating knobs. The knob located on the front side represents the Y-axis while the knob located the right side represents the X-Axis. The rotating knob is located on the left side of the aligner. Each knob contains numerical values in units of millimeters which can be used to measure the distance that the chuck moves on either axis or rotates. Together, all three knobs navigate the chuck to where the wafer needs to be
underneath the mask. A top view approach, observing directly over the wafer, should be used while positioning the chuck.

1. Adjust the X-Axis knob to move the chuck horizontally.

2. Adjust the Y-Axis knob to move the chuck vertically.

3. Adjust the rotating knob to rotate the chuck.

**Leveling the Blank Wafer and Chuck**

Located in front of the aligner is a large black dial called the Z-Axis knob. The Z-Axis knob is used to either raise or lower the chuck. The knob contains printed numerical degree values to help position the chuck from a vertical position. Here, the Z-axis knob will be used to level both the blank wafer and chuck against the mask. Leveling requires the chuck to be raised until fringe marks can be seen distributed over the wafer. An important thing to note is that both the wafer and chuck are raised until the alignment holder begins to lift up. At that point the chuck is lowered until the alignment holder returns to its original position. The chuck is raised again until the optimal position has been determined. The optimal position of the Z-Axis knob that corresponds to the optimal height of the chuck is determined when the fringes can be seen throughout the surface of the wafer and just before the alignment holder begins to lift.

Monitoring the optimal position requires both top view and cross view observations of the aligner. A top view observation is used to identify fringe marks while a cross sectional view is used to determine at what point the alignment holder begins to lift. Once the optimal position has been determined, the Ball Vac is switched to LOCK which maintains the leveling setup of the chuck. The blank wafer can now be switched with the actual wafer.

1. Use the Z-Axis knob to raise the chuck. Raise the chuck until the wafer makes direct contact to the glass slide, make note of when fringe marks begin to appear. Continue to turn the Z-Axis knob until fringe marks are visible throughout the wafer. Keep an eye on when the alignment holder begins to lift. Reverse the knob to lower the chuck if the alignment holder lifts.

2. Use the degree values on the Z-Axis knob to identify at what optimal point the wafer shows fringe over the surface.

3. Flip the LOCK Vacuum switch in Lock position to maintain the leveling setup of the chuck.

4. Carefully lower the chuck by turning in opposite direction. Turn the Z-Axis knob back 360 degrees or 1 Revolution.

5. Open the Mask Frame.

6. Turn the Substrate Vacuum Off.
7. Remove the blank wafer from the chuck.

D. UV Exposure

Complete the following steps for the UV Exposure process:

1. Remove the resist covered wafer from the 95 C hot plate if you have not already done. Allow a moment for the wafer to return to room temperature.

2. Place the wafer in approximately the same location as the blank wafer.

3. Turn the Substrate Vacuum On to secure the wafer.

4. Close the Mask Frame.

5. Use the X-Axis and Y-Axis one more time to center the wafer to exact location.

6. Begin turning the Z-Axis knob forward 1 Revolution. With the addition of the resist, the fringes marks will appear before the completion of 1 Revolution. Take notice of when the fringe marks begin to appear. Stop turning the Z-Axis knob once fringe marks become present on the surface of the wafer.

7. Check to make sure that the exposure time has been set if not already done.

8. Holding the handle carefully and pressing the button simultaneously, drag the aligner stage directly under the UV lamp. Once directly underneath, the UV lamp will turn on.

E. Removing the Wafer from the Aligner

Complete the following steps to remove wafer from UV Aligner:

1. Holding the handle and pressing button simultaneously, carefully drag the aligner stage away from the UV lamp back to its original position.

2. Turn the Nitrogen Purge switch ON. The Nitrogen Purge will help separate the mask from the wafer.

3. Turn the Z-Axis knob in reverse to lower the chuck.

4. Open the Mask Frame.

5. Turn OFF the Substrate Vacuum to release the wafer from the chuck.

6. Carefully with one finger move the wafer off from the chuck while with the fingers from the other hand support the wafer from underneath. Place the other hand that originally moved the wafer off the chuck underneath to provide additional support. Carry the wafer to the 65 C hot plate to begin Post Exposure Bake.
F. Clean up and Completion at the Aligner

Complete the following steps to undo the setup at the UV Aligner:

1. Begin removing either the Chrome or Mylar mask from the aligner. Carefully unscrew the two screws located on the front side of the aligner.

2. Carefully lift up the alignment holder that holds the glass plate.

3. Remove the screws and frames that keep the glass plate in place.

4. Turn OFF the Mask Vacuum if it’s currently ON.

5. Remove glass plate from the aligner. If a Mylar mask was used, separate the mask from the glass plate. Wipe down the corners of the mask if there’s any remaining traces of water left on the surface. Using a clean white cloth wipe down the mask with acetone to remove any residual resist that might be stuck to the mask. Place the mask back in its original container or packaging for future use.

6. Wipe down glass plate or Chrome Mask plate down with acetone. If a Chrome Mask was used, place it back in its original container. If a glass plate was used, carefully place the glass plate back in the alignment holder.

7. Reassemble the frames and re-screw the screws that secure the glass plate in place.

8. Flip over the alignment holder and carefully place it back into the aligner.

9. Re-screw the screws in the front to keep the holder in place.

10. Fill out all remaining information in the Log In sheet.

11. If no one in the clean room is planning (ASK EVERYONE IN THE ROOM) on using the UV Aligner, then turn off the aligner. In the following order, turn off the aligner first then turn off the UV lamp power box. Record the time that the UV Aligner was turned off. Once the UV Aligner has been turned off it should not be turned on for at least 30 minutes. This will allow the mercury lamp to cool and the mercury vapor to condense.
V. Post Exposure Bake

As mentioned earlier, the purpose for this Post Exposure Bake (PEB) is to remove the patterns caused by the Standing Wave effects during the UV Exposure. In addition, the process is used to complete the cross-linking process. The heat source from the hot plate helps accelerate the rate of polymerization of the epoxy group chains to form the final structure. It’s important to know that the temperature during the PEB process will cause internal stress to substrates. Thermal stress from the silicon substrate can result in the resist cracking or bending of the features. Both the temperature of the hot plates must be observed closely to avoid defects from occurring on the resist. The Microchem sheet provides recommended temperatures and times for PEB process. For more sensitive and finer features, it may be ideal to reduce the temperature slightly but increase the time of the baking process.

The following steps use the recommended temperature by Microchem:

1. Allow the wafer to sit on the 65 C hot plate for an appropriate time.

2. Once appropriate time has passed, lift the foil beneath the wafer to transport to the 95 C hot plate. Allow the wafer to sit on the 95 C hot plate for an appropriate time. Depending if the resist shows cracking due to thermal stress from the silicon substrate, a slightly lower temperature could be used. An example would be to reduce the hot plate temperature to 75 C.

3. Once the appropriate time has passed remove the wafer off the hot plate and allow it to cool to room temperature.

VI. Development

The purpose of development is to remove all soluble resist that is present on the silicon substrate. If the change of solubility of the resist after exposure was successful then it should remain intact in the development process. The developing process consists of washing the wafer in different baths: MicroChem SU-8 Developer, IPA, and distilled water. SU-8 Developer is an organic solvent that contains Propylene Glycol Monomethyl Ether Acetate (1-Methoxy-2-propyl acetate) or known as PGMEA. Once the wafer has been immersed in the developer, dissolution of the soluble resist should begin immediately. Depending on the thickness of the resist, the dissolution process can range between several seconds up to several minutes. To improve the dissolution process, an orbital shaker is used to provide uniform physical agitation of the wafer. The wafer should only have insoluble portions of resist left once the development process is complete. The wafer is then immersed into IPA which serves as a replacement solvent for the PGMEA. IPA has a higher vapor pressure than PGMEA and thus evaporates at a faster rate. The lower concentration of PGMEA, due to solvent replacement, will also evaporate at a faster rate. The wafer is then immersed in distilled water for a final cleansing of solvents then dried before undergoing a Hard Bake step. Depending on how the silicon substrate looks after development, the process might need to be repeated in order to improve the resolution of the surface. An analysis of both the thickness and the features can be done before proceeding to the Hard Bake.

Use the following steps to complete the Development process:
1. Setup up the baths for the wafer. The baths will use three white circular Teflon bowls. The first bowl will contain SU-8 Developer. The second bowl will have IPA. The last bowl will have fresh distilled water. For each bowl, fill the bowl until the height of fluid is roughly half an inch. Place all three bowls on the orbital shaker.

2. When the wafer has been cooled to room temperature, place the wafer into the first bath bowl containing SU-8 Developer solution. Located beneath the platform and in front of the equipment, turn on the orbital shaker. Adjust the speed knob so that it’s between 2 and 4. For wafers that contain smaller, narrower, or delicate features it would be best to set the orbital shaker at a slower speed. A higher speed may run the risk of lifting features up. The orbital shaker will provide uniformly agitated movements to each bath such that the development process is more thorough.

3. At this time the wafer will develop. In a perfect scenario, all of the exposed regions of the wafer should remain while the unexposed regions will be removed during the development process.

4. Once all of the resist from the unexposed regions have been removed, turn the speed knob down to 0 and carefully remove the wafer from the bath tray. To remove the wafer from the bath, simply slide it against the wall of the tray. Use the index finger of one hand to do this step. The edge of the wafer that is touching the tray will begin to lift. With the other hand, use the thumb and index finger and place each finger on opposite sides of the wafer. Once the wafer is secured by both fingers lift the wafer out of the SU-8 Developer bath and place into the IPA bath. Adjust the speed knob to the orbital shaker. Allow a few moments for the wafer to sit inside the IPA bath.

5. If the IPA bath begins to fog up with a whitish appearance once the wafer has been submerged into the solution. The surface of the wafer will also give off a whitish appearance. When this occurs simply remove the wafer from the IPA bath and place it back into the SU-8 Developer bath. Use the same technique to lift the wafer out of the bath tray as mentioned previously in step #4.

6. Once the wafer is submerged in the SU-8 Developer bath, the whitish appearance present on the surface will gradually disappear. As soon as the surface is free from any white blemishes on the surface, remove the wafer from the SU-8 Developer bath and place it back in the IPA bath. The second time that the wafer is in the IPA, the wafer should show significantly less whitish blemishes if none is seen. Allow a few moments for the wafer to sit inside the IPA bath.

7. Remove the wafer from the IPA bath and place it in the distilled water bath. Continue to use the same technique to lift the wafer out of each bath bowl.

8. While the wafer is sitting inside the distilled water bath, replace the bath bowls containing the SU-8 Developer and IPA solutions with fresh SU-8 Developer and IPA solutions respectively. All SU-8 Developer and IPA solution should go into the Waste
Drain. The Waste drain contains tubing connected underneath the sink that leads into a waste container. The Waste Drain contains concentrated wastes of acetone, IPA, and SU-8 Developer solutions. Check to see if the waste container is full. If the waste container is at least two thirds full, contact staff member immediately. The waste container should not be filled completely. Once the old SU-8 Developer and IPA have been properly discarded, rinse both bowls with distilled water. Take a clean white cloth and wipe down both bowls. Place both bowls back on the orbital shaker. Replenish each of the bowls with fresh SU-8 Developer and IPA solution.

9. Remove the wafer from the distilled water bath and place it back into the new SU-8 Developer bath. While the wafer is sitting inside the SU-8 Developer bath, take the distilled water bath bowl and empty it out in the sink (not in the Waste Drain). Because there isn’t a concentrated amount of SU-8 Developer or IPA present in the distilled water bath it doesn’t have to be poured into the Waste Drain. Rinse the bowl and replenish it with fresh distilled water. Place the bath on the orbital shaker.

10. Remove the wafer from the SU-8 Developer bath and place into the IPA bath. Allow the wafer to sit inside the bath for a few moments.

11. Remove the wafer from the IPA bath and place into the new distilled water bath. During this time discard the SU-8 Developer and IPA solutions into the Waste Drain. Thoroughly rinse out both bowls. Use a clean white cloth to dry the insides of the bowl. Turn both bowls upside down such that another user can use the bowls.

12. Remove the wafer from the distilled water bath. Carefully dry the wafer using the nitrogen gas gun. Be extremely gentle when applying nitrogen gas against the wafer surface to avoid lifting up any of the features. Continue to dry the wafer until there’s no water present on the surface. Wipe down any remaining water underneath the wafer with a cloth.

13. Once dried, the features on the substrate surface can be analyzed for thickness relative to both height and width as well as for flaws and defects. After completing the analysis to determine whether or not it can be used in the Soft Lithography process. The wafer will need to be placed on a hot plate for Hard Baking.

VII. Wafer Analysis

Analyzing the substrate surface after completing the Photolithography process is a critical check point to determine whether the wafer (SU-8 mold) can be used. Use the Profilometer when doing a thickness analysis. Refer to the Profilometer Protocol for a thorough walkthrough on how to use the equipment. In addition to thickness measurement, the wafer should be inspected by a microscope for flaws and defects that may present on the resist. These steps are important as the functionality of a microfluidic device may depend on an optimal height and width with specific structures for a design feature. Flaws and defects present on the resist have to be identified in order to determine whether or not the SU-8 mold could be used for producing.
PDMS molds in Soft Lithography. Some flaws or defects may be severe enough to render the wafer useless and therefore a new wafer would need to be made.

**VIII. Hard Bake**

The purpose of a Hard Bake is to both harden and strengthen the resist such that it remains adhered to the surface of the wafer. Any traces of solvents that may still be on the silicon substrate or the resist will be removed in the process. Hard Baking improves the features to withstand large amounts of force that is experienced during Soft Lithography when removing PDMS molds. Typically both the temperature and time for the bake is significantly higher than what is used during either the Pre-Exposure or PEB bakes.

- There’s no specific temperature that the hot plate needs to be set or how long the wafer needs to be set on the plate.

- The proper setting of the Hard Baking process should be based on temperature being inversely proportional to time. A higher temperature should be used when the wafer is placed on the hot plate for a shorter period amount of time whereas a lower temperature should be used when the wafer is placed on the hot plate for a longer period of time.

- Once the Hard Baking process is finished remove the wafer from the hot plate. Allow the wafer to cool to room temperature. At this point, the wafer will be ready for silanization.

**IX. Silanization Wafer Coating**

The purpose for silanization is to change the surface state of the silicon substrate from hydrophilic to hydrophobic by applying a thin layer of silanol molecules over the surface. The change of hydrophobicity state will reduce the likeness of resist from being pulled off by an external force such as PDMS. Although not necessary in the Photolithography process, the step can be thought of as a safety precaution. Silanization can be useful in preserving wafers that are to be used in multiple Soft Lithography processes.

Use the following steps to complete the Silanization coating process:

1. Make sure to use the vacuum desiccator chamber specifically labeled for silanization. Do not use the vacuum desiccator chambers specifically labeled for PDMS degassing.

2. Retrieve either a small eppendorf (or PCR tube) and a plastic dropper. Both of these should be located near the weighing scale. The droppers and tubes will be in close proximity to the plastic cups, Popsicle sticks, and white cloth wipes. Silanol will be aliquoted with the dropper and deposited into the eppendorf (or PCR) tube. To provide support for the eppendorf tube, locate a piece of foam. Make a small incision into the foam. Place the eppendorf tube into the incision.
3. Locate the bottle of silanol that is inside a container located on the same table. Open the container and check to see if there’s silanol fluid left inside the bottle. If there’s no fluid left inside the bottle, contact staff immediately for a replacement bottle.

4. Open the bottle and carefully aliquot approximately 1-2 drops of silanol into the tube. Close the bottle and return the bottle back into the container. Leave the container on the table. Carefully place the eppendorf tube and foam into the vacuum desiccator chamber.

5. Retrieve a plastic cup also located underneath the weighing scale. Place the cup into the vacuum desiccator chamber upside down. The plastic cup will provide an elevated platform for the wafer keeping it away from the bottom of the desiccator chamber. The bottom of the degassing chamber may have left over residue from a previous use.

6. Carefully place the wafer, with the features facing up, over the plastic cup. Make sure the wafer is centered over the cup. Place the vacuum desiccator lid directly over the bottom of container.

7. Turn on the pump. Flip the switch up to turn the vacuum pump on. Make sure the orientation of the valve is correct. The direction of the valve should be parallel to the tube that connects the gas chamber to the pump. The vacuum suction will cause the silanol to disperse inside the gas chamber. Allow the pump to run for approximately a minute.

8. Turn off pump. Flip the switch down to turn off the vacuum pump off. The silanol will gradually deposit on the surface of the gassing chamber and over the wafer. Allow the wafer to sit inside the degassing chamber for at least one hour for thorough silanization.

9. Adjust the valve knob located outside the vacuum desiccator chamber to release vacuum. Remove the lid of the gas chamber. Remove the wafer.

10. Discard the used dropper, eppendorf tube, plastic cup, and any other materials used for the silanization process.
Addendum: OAI LED LIGHT SOURCE SETUP

1. Turn ON OAI Model 200 Mask Aligner located on Aligner

2. Turn ON OAI LED Light Source. The red ON/OFF button located on the back of the light source.

3. Please wait a few moments for the software program that controls the LED Light Source software to finish loading. A Lab View touch screen panel will show which will allow users to adjust settings. Once the program finishes loading, ONLY adjust the following settings: Current and Time

4. To adjust Current press the left and right arrow buttons to decrease and increase current % respectively. The current should be set to 100%
5. To adjust Time press the seconds box. This will lead users to another screen. Simply enter the desired time value. For Example: entering in the value 50 will result in a 5.0 second exposure time. Another Example: entering in the value 255 will result in a 25.5 second exposure time. Please note that the program allows up to one decimal for exposure times similar to the Model 200 Mask Aligner.

6. Carefully position the LED Light Source directly over the Stage of the aligner. Vertically align the stage so that the tape with marked arrows is located on both sides of the stage.
7. Carefully pivot the LED Light Source so that the tape with markings located on both the LED Light Source and Model 200 Mask Aligner are aligned. Use a ruler or a long object to help correctly align the Light source directly over the stage.

8. Use the OAI 306 Power Meter to record the UV intensity of the LED Light Source. Enter in a short exposure time to measure intensity. Press the red START button to determine the UV Intensity Value of the LED Light Source. Calculate the correct exposure time by taking the appropriate Energy Dosage and dividing it by the determined UV Intensity Value.

9. Once both the alignment and exposure settings as well as other settings from the Model 200 Mask Aligner have been set (e.g. leveling chuck, activating mask and substrate vacuums, selecting appropriate contact resolution mode, intensity reading) press the red START button to begin exposure.

10. Once all exposures have been completed turn OFF the LED Light Source.

11. Turn OFF OAI Model 200 Mask Aligner.
Addendum: UV Ozone Treatment System (operational notes)

- Treatment UV
  - Clean tray
    Turn on Power located on the bottom right hand corner of tray door.
    Thoroughly spray and wipe down with a clean cloth the insides of the tray.
  - Load PDMS and glass into tray/Close Chamber
    Place the PDMS and glass content into the tray with the sides that are to be treated faced up. Close the tray.
  - Program Equipment
    Program the display located on the tray door. Set the appropriate exposure time for UV treatment. The display can be set in units of seconds, minutes, and hours.
  - Treatment
    Press Start button on display to begin UV treatment. If at any time the treatment needs to be paused or stopped, press the Stop button on the display.
  - Open Chamber
    Once treatment is finished open the tray door and remove contents.
  - Bond Contents
    Bond together the treated sides of PDMS and glass.
  - Cleanup
    Spray and wipe down the insides of the tray for the next user. Turn off power.
  - Hot Plate/oven
    For a stronger bonding between layers of the device, place assembled devices on a hot plate or an oven. Leave devices for an extended amount of time or overnight.