Standard Clean for Silicon

ESSENTIAL SAFETY PRECAUTIONS

- Verify wet process station exhaust fan operation by checking air flow at the perforated front of the bench using a piece of paper. The paper should be sucked firmly against the perforated plastic strip at the front of the wet process stations. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION*.

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, vinyl cleanroom gloves, heavy rubberized lab apron, and the yellow chemically resistant gloves.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone to summon help in the event of an emergency by dialing 911.

IMPORTANT BACKGROUND INFORMATION

- Cleaning should be performed immediately prior to any high-temperature processing. If the furnace processing cannot be performed within a few hours, the wafers will need to be cleaned again.

- Always use fresh cleaning solutions.

- Use only plastic tweezers after cleaning—metal tweezers should not be used to handle clean wafers.

- Read and understand the document "Using the Wet Process Benches."

- Use only the high-purity 18 MΩ•cm deionized water during this process.

PREPARE SOLUTIONS

1. Remove the white polypropylene lids from the clean tubs and the adjacent cascade rinse tub. Remove the inner lids from the two clean tubs. Place the inner lids in a clean place, such as on the shelf above the tubs. Be careful not to interchange the lids.

2. Turn on the heater N_2 purge valve by lifting the handle to the upright position. This purge must remain on whenever there is liquid in the tub.

3. Rinse the 1000 ml graduated cylinder and the two tubs thoroughly with deionized water. Make sure that the tub drains are open and the tubs are fully drained.

4. Close the tub drains. Measure 2500 ml of DI water into the left tub (SC-1). Measure 3000 ml of DI water into the right tub (SC-2).

5. Measure 500 ml of ammonium hydroxide (NH_4OH, green label) into the left tub.

6. Rinse the graduated cylinder with DI water.

7. Measure 500 ml hydrochloric acid (HCl, blue label) into the right tub.

8. Rinse the graduated cylinder with DI water.

9. Turn on the two temperature controllers located in the center top of the bench. The green lights should come on and indicate the present temperature of the solutions. Verify that the set points are at 80°C, by pressing the button marked *.

10. When the SC-1 solution (left tub) reaches 75°C, measure 500 ml of hydrogen peroxide (H_2O_2, purple label) into the tub.

CLEAN

11. When solution SC-1 reaches 75°C a second time, lower the wafer carrier into the tub. Start timing 15 minutes.

12. With about 5 minutes remaining of the SC-1 step:

    - Turn on the blue cascade rinse water valve to begin filling the rinse tub.
    - Measure 500 ml of hydrogen peroxide (H_2O_2, purple label) and pour it into the SC-2 (right tub). Rinse the graduated cylinder afterwards.
    - Begin to heat the furnace for the upcoming hot processing. See the SOPs for the appropriate furnace for temperatures and procedures.

13. When the 15 minutes is up, move the wafer carrier into the cascade rinse tub. Open the yellow nitrogen valve just enough to get gentle agitation of the water. Start timing 3 minutes.

14. Turn off the temperature controller for SC-1 (the left tub).

15. Remove the lids from the dilute HF tub. When the 3-minute rinse is finished, transfer the wafer carrier to the dilute HF tub. Time 15 seconds. Return the carrier to the cascade rinse for 1 minute. Replace the lids on the dilute HF tub.

16. If the SC-2 solution is at least 75°C, transfer the wafer carrier into the tub. Start timing 15 minutes. Turn off the cascade rinse water and nitrogen (blue and yellow valves).

17. With about 5 minutes left in the SC-2 etch, open the blue cascade rinse valve. When the 15 minutes are up, transfer the wafer carrier into the cascade rinse tub and open the yellow valve as before. Rinse for 3 minutes. Turn off the temperature controller for SC-2.

SPIN RINSE/DRY

18. While the wafers are in the final cascade rinse, open the "SRD NITROGEN" valve and turn on the main power switch to the spin rinser/dryer. Make sure that an empty wafer cassette is properly loaded (H-bar to the back) into the machine. When the display indicates "IDLE" press the START button. Wait for the first rinse cycle to complete, then press the STOP button twice.

19. Remove the wafers from the cascade rinse and place the carrier (H-bar in) into the spin rinser/dryer. Press the START button. Let the machine run a full cycle (about 5 minutes).

20. Turn off the power to the spin rinser/dryer. Replace the empty cassette into the machine and close the door. Close the "SRD NITROGEN" valve.

CLEAN UP

21. Open the basin rinse valve by turning the orange valve handle one-quarter turn counter clockwise.

22. Measure an additional 400 ml of ammonium hydroxide into the left tub. Use the "reagent-grade" NH4OH for this step, since it is much cheaper than the "semi-grade" chemical. (The extra NH_4OH ensures that the pH of the mixture of the acids and bases from the two tubs is within allowable limits as it is swept down the drain.)

23. Open the two drain valves, marked "DRAIN ENABLE" and "DRAIN" to allow the solutions to empty into the basin tub underneath.

24. Allow the solutions to drain completely, then rinse the tubs with plenty of DI water. Leave the toggle valves open.

25. Replace the inner tub lids and the work deck covers.

26. Turn off the basin rinse water. Turn off the heater purge nitrogen. Dry off the bench top and turn off the light. Make sure that all water and nitrogen valves are shut. Double check to be sure that everything is cleaned up and turned off.

Wet Oxidation

ESSENTIAL SAFETY PRECAUTIONS

- Verify furnace stack exhaust fan operation by checking air flow through the circular holes near the furnace tube end caps. You should hear the air whistling through the hole. Alternatively, since the fan is the same one used for the wet process stations, check to see if a piece of paper is sucked firmly against the perforated plastic strip at the front of the wet process stations. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION*.

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, vinyl clean-room gloves, and heavy insulated heat resistant gloves for those portions of the procedure involving handling hot quartzware such as the end caps. The standard cleaning procedure requires you to wear a lab coat, eye goggles and/or full-face shield, vinyl clean-room gloves, a heavy rubberized lab apron, and the yellow chemically resistant gloves.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone to summon help in the event of an emergency by dialing 911.

CLEAN

1. Prepare the wafers using the standard cleaning procedure.

LOAD

2. During the cleaning process, bring tube #3 to the "standby" state:

   Temperature: 800°C
   Ambient: 1.0 slpm dry N_2

   To set the ambient gas flow, find the flow controller for nitrogen on the oxidation control panel the set the flow to 1 slpm . (Note: A flow of 0.3 slpm of dry N_2 is the idle state of the oxidation tube.)

3. The quartz boat for tube #3 is stored in the tube and must be removed prior to loading. Using the heat-resistant gloves, remove the end cap from the tube. *Do not twist the end cap to remove it!* Instead, gently rock the cap up and down until it comes free. Place the end cap on the bench under the HEPA blower so that it can't roll off.

4. Using the push rod for tube #3, gently pull the boat out to the mouth of the tube. Using the short push rod, pull the boat onto one of the ceramic transfer plates. Place the plate with the boat on the bench opposite the furnace. Allow the boat to cool for several minutes before loading wafers.

5. Load clean, dry wafers into adjacent slots in the boat using plastic tweezers. The guard wafers should be placed on both ends of the boat to help even out gas flow and temperature distribution. (Guard wafers do not need to be adjacent to your device and test wafers.) *Make certain that you know the location of your wafers!* Getting your device wafers mixed up with guard wafers will definitely ruin your day.

6. Using the short push rod, transfer the loaded boat from the plate to back into the mouth of the furnace. Load the boat so that the "good" side of the wafers faces the far end of the tube.

7. With the boat still in the mouth of the tube, use the heat-resistant gloves to replace the end cap on the tube. Leave the cap slightly loose so that it won't become stuck when the tube changes temperature. (The end cap should have a small amount of up-and-down wiggle).

PUSH

8. Using the push rod for tube #3, slowly push the boat into the center of the furnace. The push rate should be about 1 inch every 12 seconds (5 inches per minute). This means that the total push time will be at about 5 minutes. The push rod will be flush with the front face of the furnace when the boat is in the center zone. While pushing, be careful that the push rod remains centered in the end cap hole.

9. Remove the push rod. Be careful not to catch the hook on the end cap as it is withdrawn. The rod will be very hot — *don't touch it with your free hand!*. Return the rod to its holder.

RAMP UP

10. Set the temperature controller to the desired oxidation temperature. Depending on the final temperature, it will take 10 – 20 minutes for the furnace to ramp up.

BUBBLER ON

11. While the temperature is ramping up, the bubbler can be started. First fill the bubbler with fresh DI water, using the long-necked flask reserved for this use. To fill the bubbler, remove the clamp and stopper. Add water only to the top solid line marked on the side. Do not over-fill the bubbler! Replace the stopper and the stopper clamp. Be careful not to bump the tubing in this area, as the quartz nipple at the end of the furnace tube is extremely fragile and easily broken.

12. The electrical controls for the bubbler are located on the left side of the oxidation control panel and are labeled STEAM CONTROL. Make sure that the vent bypass valve is set to VENT.

13. Power up the bubbler MFC by setting the switch to MANUAL. Set the nitrogen gas flow through the bubbler at 200 sccm.

14. Turn on the power to the bubbler temperature controller (switch directly below the controller). After a brief self-test, the bubbler temperature controller should display a set temperature of 98°C and the current water temperature. If you want to use a different water temperature, you will have to change the set point on the temperature controller. (Be sure to set it back to 98°C when you are finished.) The bubbler will heat until the actual temperature matches the set point. The heating takes 10 – 15 minutes.

OXIDATION

15. Wait until the tube temperature has settled to within ±2°C of the desired set point. Make sure the bubbler temperature is 98°C. Turn off the dry N_2 gas flow by setting its switch to OFF. Flip the vent bypass switch marked to TUBE to send the nitrogen and steam mixture into the furnace tube to start the oxidation. Start timing.

16. During very long oxidations, the bubbler must be checked every hour and refilled if the water is low. Before filling, flip the toggle switch to VENT and turn on the dry N_2 gas flow by setting its switch to MANUAL and adjusting its flow to 1 slpm. Turn off the flow of nitrogen into the bubbler by setting its flow control switch to OFF. (This prevents hot steam from burning you when you open the bubbler.) Stop timing the oxidation. Fill the bubbler as before, then resume the flow of dry N_2 to the bubbler by setting the flow control switch to MANUAL. Adding water will cool the bubbler, so you will have to wait for it to heat up again. When the temperature reaches 98°C, flip the vent bypass switch back to TUBE and shut off the flow of dry N_2. Restart timing the oxidation.

    Note: If the bubbler happens to run dry, DO NOT add water. The cold water in the hot bubbler will crack the glass. Turn off the power to the bubbler and let it cool to room temperature before adding water.

17. When the oxidation time is up, flip the vent bypass switch back to VENT and start the flow of dry N_2 gas into the furnace by setting its flow control switch to MANUAL.

BUBBLER OFF

18. Turn off the bubbler power and shut off the flow of nitrogen into the bubbler by settings its flow-control switch to OFF.

RAMP DOWN

19. Ramp down the furnace temperature. If you are planning to remove your wafers as soon as possible, ramp down to 800°C. The ramp down will require 30 - 60 minutes. If you plan to leave your wafers in the furnace overnight and remove them the next day, you can ramp to 600°C.

20. If leaving the wafers overnight, set the nitrogen flow to 0.3 slpm (the idle state) now.

PULL

21. When the tube temperature is 800°C or less, the boat can be pulled. Insert the push rod and catch the hook over one of the cross pieces on the boat. Be careful to not insert the push rod too far so that it presses against the wafers in the boat. Pull one inch every 12 seconds until the boat is in the mouth of the furnace.

    Note: Wafers can be left in the furnace overnight. The extra annealing is probably beneficial. However, it is the user's responsibility to remove the wafers in a timely manner.

UNLOAD

22. Using the heat-resistant gloves, remove the end cap and place it in on the bench under the HEPA blower. Use the short rod to pull the boat onto one of the ceramic holder plates.

23. Allow the boat to cool for several minutes and then use plastic tweezers to remove the wafers. Leave the guard wafers in the boat.

24. Replace the boat back into the mouth of the furnace tube.

25. Replace the end cap onto the furnace tube.

26. Set the furnace to 600°C and set the dry N_2 flow to 0.3 slpm.

Dry Oxidation

ESSENTIAL SAFETY PRECAUTIONS

- Verify furnace stack exhaust fan operation by checking air flow through the circular holes near the furnace tube end caps. You should hear the air whistling through the hole. Alternatively, since the fan is the same one used for the wet process stations, check to see if a piece of paper is sucked firmly against the perforated plastic strip at the front of the wet process stations. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION*.

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, vinyl clean room gloves, and heavy insulated heat resistant gloves for those portions of the procedure involving handling hot quartzware such as the end caps. The standard cleaning procedure requires you to wear a lab coat, eye goggles and/or full-face shield, vinyl clean room gloves, a heavy rubberized lab apron, and the yellow chemically resistant gloves.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone to summon help in the event of an emergency by dialing 911.

CLEAN

1. Prepare the wafers using the standard cleaning procedure.

LOAD

2. During the cleaning process, bring tube #3 to the "standby" state:

   Temperature: 800°C
   Ambient: 1 slpm dry N_2

   To set the ambient gas flow, find the flow controller for nitrogen on the oxidation gases control panel the set the flow to 1 slpm sccm. (Note: A flow of 0.3 slpm of dry N_2 is the idle state of the oxidation tube.)

3. The quartz boat for tube #3 is stored in the furnace tube and must be removed prior to loading. Using the heat-resistant gloves, remove the end cap from the tube. *Do not twist the end cap to remove it!* Instead, gently rock the cap up and down until it comes free. Place the end cap on the bench under the HEPA blower so that it can't roll off.

4. Using the push rod for tube #3, gently pull the boat out to the mouth of the tube. Using the short push rod, pull the boat onto one of the ceramic transfer plates. Place the plate with the boat on the bench opposite the furnace. Allow the boat to cool for several minutes before loading wafers.

5. Load clean, dry wafers into adjacent slots in the boat using plastic tweezers. The guard wafers should be placed on both ends of the boat to help even out gas flow and temperature distribution. (Guard wafers do not need to be adjacent to your device and test wafers.) *Make certain that you know the location of your wafers in the boat!*

6. Using the short push rod, transfer the loaded boat from the plate to back into the mouth of the furnace. Load the boat so that the "good" side of the wafers faces the far end of the tube.

7. With the boat still in the mouth of the tube, use the heat-resistant gloves to replace the end cap on the tube. Do not push the end cap on too tightly, or it will become stuck when the tube changes temperature. There should be a small amount of up-and-down wiggle possible with the end cap.

PUSH

8. Using the push rod for tube #3, slowly push the boat into the center of the furnace. Push the boat at a rate of 1 inch every 12 seconds (5 inches per minute). This means that the total push time will be about 5 minutes. When the boat is at the center of the furnace, the end of the push rod will be flush with the front face of the furnace panel. While pushing, be careful that the push rod remains centered in the end cap hole.

9. Remove the push rod. Be careful not to catch the hook on the end cap as it is withdrawn. The rod will be very hot — *don't touch it with your free hand!*. Return the rod to its holder.

RAMP UP

10. Set the temperature controller to the desired oxidation temperature. Depending on the final temperature, it will take 10 – 20 minutes for the furnace to ramp up

OXIDATION

11. Make sure that the oxygen cylinder is turned on, as detailed in the document "Using the Compressed Gas Cylinders." The main valve on the tank and the small valve on the gas line after the regulator should both be open.

12. When the furnace tube stabilizes at the set-point temperature, turn off the dry N_2 flow by setting its flow control switch to OFF. Start the oxygen flow by setting the oxygen line flow control switch to MANUAL and adjust the flow to the desired rate (typically 1 slpm). Start timing the oxidation. When the oxidation is complete, stop the O_2 flow by settings its flow control switch to OFF and start the dry N_2 flow at 0.3 slpm.

RAMP DOWN

13. Ramp down the furnace temperature. If you are planning to remove your wafers as soon as possible, ramp down to 800°C. The ramp down will require 30 - 60 minutes. If you plan to leave your wafers in the furnace overnight and remove them the next day, you can ramp to 600°C.

14. If leaving the wafers overnight, set the nitrogen flow to 0.3 slpm (the idle state) now.

PULL

15. When the tube reaches 800°C the boat can be pulled. Insert the push rod and catch the hook over one of the cross pieces on the boat. Be careful to not insert the push rod too far so that it presses against the wafers in the boat. Pull at a rate of one inch every 12 seconds until the boat is in the mouth of the furnace.

    Note: Wafers can be left in the furnace overnight. The extra annealing is probably beneficial. However, it is the user's responsibility to remove the wafers in a timely manner.

UNLOAD

16. Using the heat-resistant gloves, remove the end cap and place it in on the bench under the HEPA blower. Use the short rod to pull the boat onto one of the ceramic holder plates.

17. Allow the boat to cool for several minutes and then use plastic tweezers to remove the wafers. Leave the guard wafers in the boat.

18. Replace the boat back into the mouth of the furnace tube.

19. Replace the end cap onto the furnace tube.

20. Set the furnace to 600°C and the nitrogen flow to 0.3 slpm dry nitrogen.

Photolithography

ESSENTIAL SAFETY PRECAUTIONS

- Verify exhaust fan operation by checking air flow through the lithography chemical bench. To do this, hold a piece of paper against the perforated plastic strip at the front of the bench. The paper should be firmly sucked against the plastic strip. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION.*

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, and clean room gloves. For cleanup of the spinner and lithography station, developing the photoresist, etching the oxide layer, and stripping the photoresist, you should also wear chemically resistant gloves and a heavy rubberized apron. Goggles provide UV eye protection during photoresist exposure.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone in room 180D to summon help in the event of an emergency by dialing 911.

SPECIAL NOTE

> You should ***not*** do a standard clean immediately before doing photolithography. Experience has shown that photoresist will not stick well to silicon or silicon dioxide surfaces after a standard clean.

WARM UP and MASK ALIGNER SET UP

1. Start the vacuum pump on the floor to the left of the Karl Suss aligner.

2. Turn on the nitrogen and air switches on the front panel of the aligner.

3. Press the power button on the main console of the aligner.

4. Start the UV lamp. First turn on the power supply on the floor below the aligner. The supply will spend several seconds going through a self-test. When the display reads “rdy” (ready), press the start button on the front of the supply. The power will “beep” as it tries to light the UV bulb. Once the bulb is lit, the supply will flash the sign “cold”, meaning that the light is shining, but it needs to warm up. The warm up takes about 15 minutes. When the UV light is ready for use, the power supply will display the power being drawn by the lamp, typically around 275 watts. Make sure the power supply is set to operate in *constant intensity* (CI) mode.

5. If your mask is dirty with photoresist or other particles, clean it with acetone and then methanol. Dry the mask thoroughly by putting it on a clean room wiper in the pre-bake oven.

6. Once the mask is clean, place the mask on the holder. Make sure that the chrome side is facing away from the holder and that the vacuum ring is covered completely. Push the vacuum mask button to secure the mask to the holder. Slide the holder into the slot on the aligner and tighten the two set screws to "hold the holder" in place.

   Note: Paying attention to how the mask is positioned on the holder can simplify the aligning process.

WAFER PRIME

7. Place the 2-3/4 inch diameter chuck on the spinner shaft. To do this, carefully align the flat on the spinner shaft with the corresponding flat in the white plastic insert in the chuck before gently pressing the friction-fit chuck onto the shaft. Make sure the chuck is square to the shaft axis. Misalignment and excessive force will gall the plastic insert and make it very difficult to install or remove the chuck.

8. Power up on the spinner by turning on the switch marked SPINNER OUTLET on the top left edge of the hood. You should hear the vacuum pump start running.

9. Using metal tweezers, center the first wafer on the chuck.

10. Start the spinner by stepping on the front part of the foot switch. Set the rotation speed and spin time on the controller located in the cabinet below the process bench. Typical spin parameters are 3000 - 4000 rpm for 20 - 40 seconds. While checking the spin speed and time, verify that the drain tube from the spinner is in the mouth of the waste bottle under the spinner and that the bottle is not full. If it is full, contact your lab instructor and have it replaced before proceeding.

11. Fill the squeeze dropper of the amber bottle containing the adhesion promoter marked HMDS (hexamethyldisilazane) and put three or four drops in the center of the wafer.

12. Immediately start the spinner using the foot switch. The spinner will automatically shut off at the end of the set time.

SPIN PHOTORESIST

13. Fill the squeeze dropper of the amber photoresist bottle about half full. Avoid forming bubbles in the photoresist.

14. Gently squeeze the photoresist onto the center of the wafer. Replace the dropper in the amber bottle.

15. Immediately start the spinner using the foot switch. The spinner will automatically shut off at the end of the set time.

16. Remove the wafer from the chuck using metal tweezers. Return the wafer to the wafer carrier.

17. Repeat step 11, and steps 13 - 18 for each of the remaining wafers.

Note: In unusual circumstances, use of the HMDS alone may not be sufficient to give adequate adhesion. If you experience a problem with photoresist peeling off, you can add an extra dehydration bake to the process as a means to help promote adhesion. If you choose to do this, you should spin HMDS on *all* your wafers and then put all of the wafers in pre-bake oven (set at about 85°C) to bake for 30 minutes. After the bake, remove the wafers and let them cool. Finally, proceed with spinning photoresist on each of the wafers.

PREBAKE

18. Place the wafer carrier into the left-hand oven and pre-bake the wafers at 80°C - 90°C for 25 minutes.

    Alternative pre-baking method: If you have only one or two wafers, you might save time by using the hot plate to pre-bake the wafers. The hot plate is located under one of the covers in the hood. To use the hot plate remove the cover and set it aside. Then turn on the hot plate controller, which located in the head panel of the hood. A typical time and temperature for a hot-plate pre-bake are 1 minute at 120°C. However, *you will need to optimize these numbers for your own process*. The success of the hot-plate pre-bake is very dependent on the thermal transfer from the hot plate to the photoresist on the top surface.

SPINNER CLEAN UP

19. Turn off the power to the spinner.

20. Put on the chemically resistant gloves. Get two or three clean room wipes and lay them out on the lithography station work deck. Fill the acetone and methanol squeeze bottles, if they are nearly empty.

21. In the fume hood directly opposite the lithography wet bench station, open the acetone/ methanol waste bottle and insert a large funnel into the opening.

22. Remove the spinner chuck. If it is clean, put it back on the shelf. It there is photoresist on it, set it one of the wipers you laid out previously.

23. Remove the inner bowl from the spinner. Hold the spinner bowl over the funnel so that the bowl's drain empties into the waste bottle. Use acetone from the squeeze bottle to rinse the

photoresist out of the bowl. This may require a few minutes of rinsing, depending on how much photoresist was in the bowl.

24. After the photoresist is gone, rinse the bowl with methanol from the squeeze bottle.

25. Wipe out the bowl with one of the wipers and put it back into the spinner.

26. If the spinner chuck has photoresist on it or if photoresist splashed onto the lithography station work deck, use ***a few drops*** of acetone on a wiper to clean up.

27. Remove the funnel from the waste bottle and replace the lid.

28. Leave the wipers in the hood to dry out. Throw them into the garbage after they have dried.

ALIGN AND EXPOSE WAFER

29. Turn on the aligner's microscope light, located on top of the mask aligner.

30. Select the contact mode that will be used. (Soft contact for EE 432/532 litho.)

31. Set the microscope so that only one objective is being used, i.e. *not* in split-field mode.

32. Focus the microscope on the features of the mask.

33. Choose the wafer chuck that you will use and mount it on the wafer tray.

34. Set the photoresist-covered wafer on the wafer chuck. Make sure that the wafer is oriented the same way as the mask.

35. Slide the wafer tray into the aligner so that the wafer is underneath the mask.

36. Bring the wafer into contact with the mask. To do this, *slowly* rotate the small lever on the left side of the aligner counter-clockwise (from pointing towards the back to pointing towards the front). Observe the wafer coming towards the mask, watching for contact. The wafer and the mask should make contact when the lever has gone through about 90% of its rotation. (When the lever is pointing to the "10 o'clock" position.) It is likely that you will need to make z-axis adjustments in order to get the mask and wafer to contact at the proper point of rotation. To adjust the z-axis separation, slowly rotate the lever all the way clockwise, so that the wafer is all the way down. Adjust the separation by turning the knob on the front of the aligner. Turning the knob clockwise increases the separation (numbers on the dial increase); counter-clockwise rotation decreases the separation (numbers decrease). After adjusting the z-axis, check the contact again by rotating the lever and watching for the point where the mask contacts the wafer. Repeat the z-axis adjustment process as needed until the wafer and the mask make contact at the correct position. Note: Do not make z-axis adjustments unless the lever is in its fully clockwise position (all the way back). When you are satisfied that

they are making good contact, rotate the lever all the way counter-clockwise (all the way forward). The CONTACT light on the front panel will turn on.

NOTE! The CONTACT light does *not* mean that the wafer and mask are in contact! It only indicates that the raising/lowering lever is in its fully counter-clockwise position. If the z-axis adjustment was not done properly, there could still be a huge separation between mask and wafer even though the contact light is glowing. Do not be fooled by this.

37. Once the wafer and mask are in good contact you can begin the alignment process. To start the process, move the separation lever all the back (towards you). This moves the wafer down from the mask by a fixed amount (about 35 μm) so that the wafer can be moved relative to the mask. The SEPARATION light on the front panel will light up. DO NOT use the z-axis control to introduce separation!

38. Start the alignment process by using the x- and y- controls to position a set of alignment marks on the wafer so that they are directly below a set of alignment marks on the mask.

39. Adjust the rotation control so that lines on the wafer and on the mask are roughly parallel to each other.

Note: If you were not careful in placing the wafer on the chuck or in mounting the mask on the mask holder, the relative rotation of the mask and wafer may be so far apart that you will not be able to align them with the rotation control. In that case, you will have to remove the wafer from the aligner, shift its position on the wafer chuck, and then start the process over.

40. Now put the microscope into split-field mode and adjust the microscope so that the two objective lenses are looking at different alignment marks.

41. Use the rotation, x-axis, and y-axis controls to adjust the alignment until both sets of alignment marks are aligned to your satisfaction.

42. When you are satisfied that the alignment is adequate, push the separation level all the way forward, bringing the wafer back into contact with the mask. The SEPARATION light will go out.

43. Set the exposure time. The large outer dial sets the number (between 0 and 3), the inner dial sets the units (seconds, tens of seconds, minutes, tens of minutes).

44. Put on the UV goggles. Warn everyone else in the room that the UV light is about to come on.

45. If you are using HP mode, press the VACUUM PRESSURE button the front console. This pulls a vacuum between the mask and the wafer. Check the alignment one more time while the vacuum in on.

46. Hit the exposure button. The upper assembly of the aligner should move forward so that the UV lamp is over the mask. (Note: Our mask aligner has a peculiar characteristic in which, occasionally, the upper assembly will not move forward. If this happens, use the microscope position control to move the microscope all the way towards the *back*. The changes the balance of upper assembly so that it will move correctly.) The upper assembly will move back when the exposure is complete.

47. If you were using HP mode, press VACUUM PRESSURE to release the vacuum.

48. Rotate the raising/lowering lever clockwise to its fully back position.

49. Remove the wafer.

DEVELOP PHOTORESIST

50. Put on a pair of chemically resistant gloves. Fill a deep glass dish with about 1 cm MIF-300 developer. Fill the cascade rinse tub and place a wafer carrier in the DI water.

51. Using metal tweezers, place a wafer into the developer. Gently agitate the wafer in the solution for 60 - 90 seconds. You should be able to see when developing is complete.

52. Place the wafer in the carrier that is in the rinse tub. Rinse for at least three minutes.

53. Developing any remaining wafers, putting each into the cascade rinse tub.

54. Dry all the wafers on a clean room wiper using nitrogen.

55. Dispose of the used developer by pouring it into the labeled waste bottle. Rinse the developer dish thoroughly and leave on the bench top to dry.

INSPECT

56. Inspect the wafers using the microscope. Make sure the yellow filter for the microscope light is in place by checking that the letter "Y" on the front filter wheel is adjacent to the white dot. Check for square corners, complete removal of photoresist, etc. Generally, it is not necessary to inspect every wafer. If the wafers have been slightly underexposed, it may be possible to return them to the developer and salvage them. Processing should not continue unless alignment is satisfactory. The photolithography step can be repeated if necessary — see your lab instructor.

57. If desired, a photograph of the wafer can be obtained using the digital camera on the microscope. Refer to the microscope instructions in the section on general lab procedures.

MASK ALIGNER SHUT DOWN

58. Once you are satisfied that the photoresist patterns on all your wafers are good enough, you can shut down the mask aligner. Do the following steps in order: Remove the mask and store it in its box. Turn off the microscope lamp and video monitor. Turn off the UV lamp supply. Turn off the power to the aligner and close the air and vacuum switches. Finally, turn off the vacuum pump.

POSTBAKE

59. If needed, a post-bake of the photoresist can be done on the hot plate or in the left-hand oven. The temperature for the oven or the hot plate should be 120°C. Postbake the wafers for the desired time.

    Note that in some cases, it may not be necessary to use a postbake step. However, if you choose to forgo the postbake, you should check the stability of the photoresist during etching.

ETCH

60. Etching is done at the wet-process bench located in the furnace room (180-D). See the handout "Using the Wet Process Benches" for more information about the bench layout.

61. Place the wafer carrier in the BOE (buffered oxide etch) tub. Check the etch periodically to see if it is complete. The etch rate can be empirically determined or test wafers can be used to determine the stopping point. On the test wafer, watch for the change from hydrophilic (wetting) to hydrophobic (non-wetting) behavior. You might want to give the devices wafers another 30 seconds of etching to ensure complete removal of the oxide layer.

62. When completely etched, rinse the wafers in the cascade rinse tub for 2 minutes.

PHOTORESIST STRIP

63. Place the carrier in the acetone #1 tub for 3 minutes.

64. Place the carrier in acetone #2 for 1 minutes.

65. Place the carrier in the methanol tub for 1 minute.

66. Rinse in the cascade rinse tub for 2 minutes.

67. Rinse and dry the wafers in the spin rinser/dryer.

CLEAN UP

68. Replace and tightly seat all tub lids and replace all work deck covers. Use the DI water hand spray to wash any drops of buffered oxide etching acid off the work surface toward the perforated plastic strip at the back of the wet process station. Allow any drops of solvent to evaporate.

Boron Deposition

ESSENTIAL SAFETY PRECAUTIONS

- Verify furnace stack exhaust fan operation by checking the air flow through the circular holes near the furnace tube end caps. You should hear the air whistling through the hole. Alternatively, since the fan is the same one used for the wet process stations, check to see if a piece of paper is sucked firmly against the perforated plastic strip at the front of the wet process stations. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION.*

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, vinyl clean room gloves, and heavy insulated heat resistant gloves for those portions of the procedure involving handling hot quartzware. The standard cleaning procedure requires you to wear a lab coat, eye goggles and/or full-face shield, vinyl clean room gloves, a heavy rubberized lab apron, and the yellow chemically resistant gloves. The deglazing step requires the same attire.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone to summon help in the event of an emergency by dialing 911.

CLEAN

1. Clean the wafers using the standard cleaning procedure.

PREPARE SOURCE BOAT

2. The wafer boat should be located at the center of the furnace. The furnace temperature should be at the idle value of 400°C.

3. Insert the long push rod through the hole in the end cap. Hook the source boat and slowly pull it to the mouth of the furnace. Pull at a rate of about 2 inches every 12 seconds. (Twice the normal push/pull rate, because the furnace is cooler.)

4. Remove the end cap from the boron deposition tube (Tube #2) and place it on the bench under the HEPA blower so that it can't roll off.

5. Use the short push rod to pull the boat onto one of the white holder plates. Remember that the plate will get hot where the boat touches it.

6. Place the plate and boat on the counter to cool.

7. *RAMP UP*

8. Set the tube #2 temperature controller to 850°C.

9. Set the gas flow in tube #2 to 2 slpm of nitrogen.

LOAD WAFERS

10. *Using plastic tweezers*, remove guard wafers from the slots adjacent to the source wafers to make room for your silicon wafers. Put the guard wafers into empty slots at either end of the boat.

11. Place your silicon wafers into the empty slots adjacent the source wafers, with the side to be doped facing the source wafer. All slots next to the source wafers should be filled – use guard wafers next to the source wafers not being used for your silicon. Keep track of the location of your wafers in the boat.

12. Using the short push rod, push the quartz boat from the plate into the mouth of the furnace tube.

13. Replace the end cap on the tube.

14. Using the long push rod for tube #2, push the boat into the center zone of the furnace at a rate of 1 inch every 12 seconds.

RECOVERY

15. Open the oxygen gas cylinder valve and the valve after the regulator. (See the document titled *Using compressed gas cylinders* from the dry oxidation section.) Turn on the oxygen flow (switch set to MANUAL) and set the oxygen flow meter to 1 slpm. Decrease the nitrogen flow to 1 slpm, so that he total flow remains at 2 slpm.

16. Continue the oxygen/nitrogen gas flow for 20 minutes.

SOURCE

17. Open the hydrogen cylinder valve and regulator valve. Turn on the hydrogen flow (gas control switch to MANUAL) and adjust the hydrogen flow to 40 sccm. Let the hydrogen flow for 2 minutes, and then shut off the hydrogen. Close the cylinder and regulator valves.

SOAK

18. Shut off the oxygen flow and increase the nitrogen flow to 2 slpm. Close the oxygen cylinder and regulator valves.

19. Leave the wafers in the furnace for the desired soak time. (The soak time is a design parameter and determines the total dose of boron in the silicon wafer. It will be different for every process.) Note that dopant will continue to soak into the wafers during the pull step, so you should add the pull time to the total soak time.

PULL

20. Insert the push rod, hook the boat, and pull it to the mouth of the tube at the rate of 1 inch each 12 seconds.

21. Remove the end cap and place it on the bench under the HEPA blower so that it can't roll off.

22. Using the short push rod, pull the boat onto a white plate, put the plate on the counter, and let the boat cool for several minutes.

23. Reduce the boron furnace temperature to 400°C, and set the nitrogen flow to 0.3 slpm.

UNLOAD

24. After the source boat has cooled, use plastic tweezers to remove your process wafers and and transfer them to a teflon wafer carrier. Fill the empty slots in the boat with guard wafers from the ends of the boat.

25. Using the short push rod, put the boat back into the mouth of tube #2.

26. Replace the end cap on the tube.

27. Push the boat to the center of the tube with the long push rod at a rate of 1 inch every 12 seconds.

DEGLAZE

28. Etch the wafers in the BOE tub for 30 seconds.

29. Cascade rinse for at least 3 minutes. This is a good time to rinse down the spin rinser/dryer.

30. Spin rinse/dry the wafers.

Boron Drive

ESSENTIAL SAFETY PRECAUTIONS

- Verify furnace stack exhaust fan operation by checking air flow through the circular holes near the furnace tube end caps. You should hear the air whistling through the hole. Alternatively, since the fan is the same one used for the wet process stations, check to see if a piece of paper is sucked firmly against the perforated plastic strip at the front of the wet process stations. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION*.

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, vinyl clean room gloves, and heavy insulated heat resistant gloves for those portions of the procedure involving handling hot quartzware such as the end caps. The standard cleaning procedure requires you to wear a lab coat, eye goggles and/or full-face shield, vinyl clean room gloves, a heavy rubberized lab apron, and the yellow chemically resistant gloves.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone to summon help in the event of an emergency by dialing 911.

A typical boron drive involves three steps: 1) a low-temperature oxidation (LTO) needed to remove the boron skin formed during boron deposition, 2) a wet oxidation to grow new oxide over the exposed areas of the silicon wafer, and 3) a drive step to push the dopant deeper into the wafer. The LTO step is always required, but what follows depends that on your particular process. The sequence listed below describes the usual process in which the LTO is followed by a short wet oxidation and then a longer drive in dry nitrogen. If your process differs from that, you will have to modify the steps after LTO to correspond to your desired process.

CLEAN

Note: If you are going directly from the boron deposition step to the boron drive step, you can skip the wafer clean. You should clean the wafers if any appreciable time has elapsed since the boron deposition (i.e. overnight) or if any other processing or wafer testing has been performed on the wafers after the boron deposition.

1. Prepare the wafers using the standard cleaning procedure.

FURNACE and BUBBLER RAMP UP

2. During the cleaning process, bring tube #3 (oxidation) to the “standby” state:
   Temperature: 800°C
   Ambient: 1 slpm dry N_2

To set the ambient gas flow, find the flow controller for nitrogen on the oxidation gases control panel the set the flow to 1 slpm. (Note: A flow of 0.3 slpm of dry N_2 is the idle state of the oxidation tube.)

3. While the temperature is ramping up, the bubbler can be started. First fill the bubbler with fresh DI water, using the long-necked flask reserved for this use. To fill the bubbler, remove the clamp and stopper. Add water only to the top solid line marked on the side. Do not over-fill the bubbler! Replace the stopper and the stopper clamp. Be careful not to bump the tubing in this area, as the quartz nipple at the end of the furnace tube is extremely fragile and easily broken.

4. The electrical controls for the bubbler are located on the left side of the oxidation gases control panel and are label STEAM CONTROL. Make sure that the vent bypass valve is set to VENT.

5. Start the nitrogen gas flow through the bubbler by setting the switch to MANUAL. Set the nitrogen gas flow into the bubbler at 200 sccm.

6. Turn on the power to bubbler temperature controller (switch directly below the controller). After a brief self test, the bubbler temperature controller should display a set temperature of 98°C and the current temperature of the water in the bubbler flask. If you want to use a different water temperature, you will have to change the set point on the temperature controller. (Be sure to set it back to 98°C when you are finished.) The bubbler will heat until the actual temperature matches the set point. The heating takes approximately 15 minutes.

LOAD

7. The quartz boat for tube #3 is stored in the mouth of the tube and must be removed prior to loading. Using the heat-resistant gloves, remove the end cap from the tube. *Do not twist the end cap to remove it!* Instead, gently rock the cap up and down until it comes free. Place the end cap on the bench under the HEPA blower so that it can't roll off.

8. Using the short push rod for tube #3, gently pull the boat onto one of the ceramic holding plates. Place the plate with the boat on the bench opposite the furnace. Allow the boat to cool for several minutes before loading wafers..

9. Load clean, dry wafers into adjacent slots in the boat using plastic tweezers. The guard wafers should be placed on both ends of the boat to help even out gas flow and temperature distribution. (Guard wafers do not need to be adjacent to your device and test wafers.) *Make certain that you know the location of your wafers!*

10. Using the short push rod, load the boat from the plate into the mouth of the tube. Load the boat so that the device side (polished side) of the wafers faces the far end of the tube.

11. With the boat still in the mouth of the tube, use the heat-resistant gloves to replace the end cap on the tube. Do not push the end cap on too tightly or it will become stuck when the tube changes temperature. There should be a small amount of up-and-down wiggle.

PUSH

12. Using the push rod for tube #3, slowly push the boat into the center of the furnace at a rate of 1 inch every 12 seconds (5 inches per minute). The total push time will be about 5 minutes. The push rod will be flush with the front face of the furnace when the boat is in the center zone. While pushing, be careful that the push rod remains centered in the end cap hole.

13. Remove the push rod. Be careful not to catch the hook on the end cap as it is withdrawn. Do not touch the push rod as it is very hot. Return it to its holder.

LOW TEMPERATURE OXIDATION (LTO)

14. Make sure the bubbler temperature is 98°C. Turn off the dry N_2 flow (flow control switch to OFF). Flip the vent bypass switch to TUBE and start timing.

15. When the oxidation time is up (typically 30 minutes), flip the vent bypass switch back to VENT and start the flow of dry N_2 gas into the furnace by setting its flow control switch to MANUAL.

UNLOAD AND DEGLAZE

16. Insert the push rod and catch the hook over one of the cross bars on the boat. Be careful to keep the push rod from contacting the wafers in the boat. Pull at a rate of one inch every 12 seconds until the boat is in the mouth of the furnace.

17. Using the heat-resistant gloves, remove the end cap and place it in on the bench under the HEPA blower. Use the short rod to pull the boat onto one of the ceramic holder plates.

18. After the wafers have cooled, transfer them to a teflon wafer carrier.

19. Etch the wafers in the BOE tub for 30 seconds.

20. Cascade rinse for at least 3 minutes. This is a good time to rinse down the spin rinser/dryer (if necessary).

21. Spin rinse/dry the wafers.

RE-LOAD WAFERS for OXIDATION/DRIVE

22. Transfer the wafers back to the oxidation boat.

23. Using the short push rod, transfer the boat from the white holder plate back into the mouth of the furnace.

24. Replace the end cap.

25. Using the push rod for tube #3, slowly push the boat into the center of the furnace at a rate of 1 inch every 12 seconds. While pushing, be careful that the push rod remains centered in the end cap hole.

RAMP UP

26. Ramp the oxidation tube to the desired drive temperature.

27.While the furnace is ramping up, check the water level in the bubbler, and fill it, if needed.

OXIDATION

28. Wait until the tube temperature has settled to within ±2°C of the desired set point. Make sure the bubbler temperature is 98°C. Turn off the dry N_2 gas flow by setting its switch to OFF. Flip the vent bypass switch marked to TUBE to send the nitrogen and steam mixture into the furnace tube to start the oxidation. Start timing.

BUBBLER OFF / BORON DRIVE

29. At the end of the oxidation period, turn off the bubbler power and shut off the flow of nitrogen into the bubbler by setting its flow-control switch to OFF.

30. Turn on the flow of dry nitrogen to the tube, and adjust it to 1.0 slpm. Continue with the drive step.

RAMP DOWN

27. At the end of the drive step, ramp down the furnace temperature. If you are planning to remove your wafers as soon as possible, ramp down to 800°C. The ramp down will require 30 - 60 minutes. If you plan to leave your wafers in the furnace overnight and remove them the next day, you can ramp to 600°C and set the nitrogen flow to 0.3 slpm.

PULL

28. When the tube temperature is 800°C or less, the boat can be pulled. Insert the push rod and catch the hook over one of the cross pieces on the boat. Be careful to not insert the push rod too far so that it presses against the wafers in the boat. Pull at a rate of one inch every 12 seconds until the boat is at the mouth of the furnace.

Note: Wafers can be left in the furnace overnight at 600°C. The extra annealing is probably beneficial. However, it is the user's responsibility to remove the wafers in a timely manner.

UNLOAD

31. Using the heat-resistant gloves, remove the end cap and place it in on the bench under the HEPA blower.

32. Using the short push rod, pull the boat onto one of the transfer plates.

33. Allow the boat to cool for several minutes, and then use plastic tweezers to remove the wafers. Leave the guard wafers in the boat.

34. Use the transfer plate and short push rod to return the boat in the mouth of the furnace tube.

35. Replace the end cap onto the furnace tube.

36. Set the furnace to 600°C and the nitrogen flow to 0.3 slpm dry nitrogen.

Phosphorus Deposition

ESSENTIAL SAFETY PRECAUTIONS

- Verify furnace stack exhaust fan operation by checking air flow through the circular holes near the furnace tube end caps. You should hear the air whistling through the hole. Alternatively, since the fan is the same one used for the wet process stations, check to see if a piece of paper is sucked firmly against the perforated plastic strip at the front of the wet process stations. *DO NOT PROCEED IF THERE IS NOT ADEQUATE VENTILATION*.

- Assemble and don the personal protective equipment required for this procedure: lab coat, eye goggles, vinyl clean room gloves, and heavy insulated heat resistant gloves for those portions of the procedure involving handling hot quartzware such as the end caps. The standard cleaning procedure requires you to wear a lab coat, eye goggles and/or full-face shield, vinyl clean room gloves, a heavy rubberized lab apron, and the yellow chemically resistant gloves. The deglazing step requires the same attire.

- Note the location of the safety shower and eyewash station and check to make sure the path is clear of obstructions.

- Note the location of the telephone to summon help in the event of an emergency by dialing 911.

CLEAN

1. Clean your wafers using the standard cleaning procedure.

PREPARE SOURCE BOAT

2. Phosphorus doping wafers are stored in the center of the phosphorus tube at 400°C with dry nitrogen gas flowing.

3. Insert the long push rod through the hole in the end cap, use the hook to catch the boat, and slowly pull the boat from the center of the tube to the mouth. Pull at a rate of 2 inches every 12 seconds (twice the usual rate because the furnace is cooler).

4. Using the heat resistant gloves, remove the end cap from the phosphorus tube. Do not twist the end cap to remove it! Instead, gently rock the cap up and down until it comes free. Place the end cap on the bench under the HEPA blower so that it can't roll off.

5. Using the short push rod, pull the boat onto the holder plate. Place the plate with source boat on the counter to cool.

RAMP UP

6. Begin ramping the phosphorus tube temperature to 900°C.

7. Set the N_2 gas flow in the phosphorus tube to 1 slpm.

LOAD WAFERS

8. *Using plastic tweezers*, remove guard wafers from the slots adjacent the source wafers to make room for your process wafers. Put the guard wafers into slots at either end of the boat.

9. Place your silicon wafers in the slots adjacent to the source wafers. Make sure that the side to be doped is facing the phosphorus wafer. Fill all slots between the source wafers, using spare guard wafers you don't have enough silicon wafers to fill all the available slots. Keep track of the location of your wafers in the boat.

10. Using the short push rod, push the phosphorus boat from the plate into the mouth of the furnace tube.

11. Replace the end cap on the tube.

PUSH

12. When phosphorus tube had reached 900°C, use the long push rod for the phosphorus tube to push the boat into the center zone of the furnace at the rate of 1 inch every 12 seconds. The end of the push rod will be flush with the front face of the furnace when the boat is at the center of the furnace.

13. Remove the push rod. Be careful not too hook it on the end cap as it is withdrawn. Be careful in handling the push rod, as it will be hot.

SOURCE

14. When the boat reaches the center of the tube, begin timing the source process for the required period. This is the source step during which time the total dose of phosphorus in the silicon wafer is set.

PULL

15. When the source step is complete, use the push rod to pull the wafers to the mouth of the furnace at a rate of 1 inch every 12 seconds. Include the time for the pull in the total sourcing time for the deposition.

16. Remove the end cap and place it on the bench under the HEPA blower so that it can't roll off.

17. Using the short push rod, pull the boat onto the white plate. Put the plate on the counter, and allow the boat to cool for several minutes.

18. Reduce the furnace tube to 400°C.

19. Reduce the nitrogen gas flow to 0.3 lpm.

UNLOAD

20. After the boat has cooled, remove your silicon wafers and place guard wafers into the slots adjacent to the source wafers.

21. Using the short push rod, load the boat back into the mouth of the furnace

22. Replace the end cap on the tube

23. Push the boat back to the center of the furnace at a rate of 1 inch every 12 seconds.

DEGLAZE

24. Put on the proper protective equipment. Etch the wafers in the BOE tub for 30 seconds.

25. Cascade rinse for at least 3 minutes. This is a good time to rinse down the spin rinser/dryer.

26. Spin rinse/dry the wafers.

PHOSPHORUS DRIVE

27. Typically after the deposition, a phosphorus drive is done in the oxidation furnace. This is similar to a boron drive, except that there is no need for the low-temperature oxidation. The silicon wafers can be loaded immediately into the oxidation furnace. The drive usually consists of an short oxidation step to grow a masking oxide along with a longer drive in nitrogen to achieve the desired phosphorus doping profile.

Electron beam evaporator

Preliminary considerations

- With the electron-beam evaporator, user safety is essential. Also, since the evaporation equipment is relatively complex, improper use can lead to damage requiring expensive and time-consuming repairs. All users must be properly trained. A list of qualified users is posted on the side panel of the e-beam equipment rack. If your name is not on that list, YOU ARE NOT ALLOWED TO USE THE EVAPORATOR, and will need to have a qualified user operate the system for you.

- Several aspects of the use of the e-beam system require good judgment on the part of the operator. These include beam alignment, proper mounting of samples, (particularly samples that are of an unusual size or shape), and replacing the crystal sensor. Even experienced users may be uncertain about proper procedures in these special circumstances. If you have any doubts the use of the evaporator, be sure to get help. The extra time used in getting assistance may well save days or weeks of delay if the machine is damaged through your poor judgment.

Loading samples

1. Turn on the mechanical pump using the breaker switch on the front panel (lower left) of the Temescal system

2. Push the AUTOSTOP button on the Temscal to start the venting sequence. You will hear the valve to the main cryopump close immediately. Turn off the filament to main chamber ion gauge. After a delay of several seconds, the nitrogen gas valve will open, and you will hear the system begin to vent.

3. The system will be vented after 2-3 minutes, and you will be able to open the lid to the chamber. Once the system is vented, you can stop the nitrogen flow (saves on nitrogen gas use) by setting the N_2 vent auto/manual switch to manual.

4. Move the carousel to the desired source material. Open the shutter by moving Shutter 1 switch to OPEN to reveal the source. Check the source to make certain there is sufficient material for evaporation. Add more, if needed. (You can remove the sample holder to give better access to the source carousel.) Close the shutter.

5. Check the health of the crystal sensor. (Parameter 36 on the controller.) If it is below 50%, the sensor should probably be replaced.

6. Load wafers into the sample holder. (If working with 2-inch wafers, you will need to change the sample holder.) If working with small samples or anything that might easily fall into vacuum chamber, it is probably wise to remove the sample holder to the table and mount

samples there. When re-installing the sample holder assembly, be sure that the shield aligns with the thickness monitor.

7. Once samples are securely mounted onto the holder, check the sealing surface on the lid. Remove any large particles using a clean room wiper.

8. Set the N2 vent manual/auto switch back to the auto position. Start the pumping-out process by pushing the AUTOSTART button. After a delay of 2-3 seconds, the valve to the mechanical pump will open and the system will start roughing down.

9. After 10-15 minutes, when the system pressure reaches 50 mTorr, the valve to the mechanical pump will close, and the valve to the cryopump will open. You should see the pressure drop rapidly. At this point, you can turn off the mechanical pump (breaker switch on front panel) and turn on the filament to the ion gauge.

10. Wait until the system has pumped down to at least $5x10^{-6}$ Torr before attempting the evaporation. This will take at least two hours.

Powering up

11. Log in on the computer so that your work is recorded. Also, open the "Evaporator Log" Excel file that is in the "NSF Lab stuff folder". In the Log file, review the most recent entry for the type of material that you intend to deposit today. This will give you an idea about the types of power levels that will be needed for your deposition.

12. Turn on the breaker switch that is on the CV-8 power supply (behind the main part of the e-beam system). All of the amber lights on the CV-8 control panel should be lit. If not, there is a problem with the system, and you should get help. (Before getting help, check that the key on the control panel is inserted and switched on.)

13. Activate the high voltage by depressing the HV ON button. The button should light up.

14. Activate the gun filament by depressing the GUN 1 FIL ON button. The button should light up.

15. Start the sample rotation by setting the sample rotation switch to ON.

16. Make certain that the source carousel is set to the correct crucible position for the material you want to deposit.

17. Reset the controller by pushing the RESET button. Put the controller into manual mode. (The AUTO/MANUAL button is near the center-bottom of the process control panel.) The red MANUAL indicator light should be on.

18. Set process number on the controller to the material you will be depositing. Set the film number to the material you will be depositing. Confirm that the film density (parameter 28) and acoustic impedance (parameter 31) settings correspond to the material you are depositing. If not, enter the correct values for these two parameters. A list of material densities and acoustic impedances is posted on the side of the e-beam control rack.

19. *Slowly* ramp the controller power to 12-13%. The ramp time should be at least 2 minutes.

    Note: When using the manual operation remote, the toggle lever is sticky. When ramping power up or down, be sure to return the toggle to the neutral position.

20. At 12% power, you should be able to look through the viewport and see the electron beam striking the source material. Remember to open the viewport shutter. Also, you might need to advance the viewport protection film, if the current viewing spot has been coated. If needed, you can adjust the power upwards slightly to get a better view of the beam on the source.

21. Adjust the beam position and sweep. Start by turning the longitudinal and latitudinal sweep amplitudes to zero. Use the long. and lat. beam position controls to locate the beam at the center of the source material. Then increase the two sweep amplitudes until the beam is sweeping over most of the source material, making certain that the beam does not extend outside the crucible.

22. Go to the Manual deposition or Automatic deposition sections below depending on which method you will use for your deposition.

Manual deposition

23. Continue slowly ramping the source power to a level just slightly below the value you think will be needed for desired deposition rate. (You should have some idea of this value based on previous experience or by consulting the log.) It is advisable to check on the hot source through the viewport occasionally as the power is ramped up.

24. After ramping up, let the crucible stabilize for at least one minute.

25. Open the shutter using the "SHUTTER 1 switch. If the beam power is sufficient, the growth rate indication will be greater than zero and the thickness will start to increase. (If the growth rate is still zero, you will have to continue ramping up the power until some growth rate shows up). Slowly adjust the power to get the desired deposition rate.

26. Monitor the rate during the deposition. Since the system is running "open-loop", there will variations in the deposition rate. Don't try to compensate for every small variation. Instead

to try to use a "mental average" over 10 or 15 seconds to gauge whether the power should be adjusted. Typically, the average deposition rate will drop during the deposition, and gradual increase in power will be needed to keep the rate approximately constant.

27. When the desired thickness has been reached, close the shutter by moving the SHUTTER 1 switch to the AUTO position.

28. Slowly ramp the power down to zero.

Automatic operation

--- This section is currently incomplete. ---

Powering down and unloading

31. After the power has been ramped to zero, turn off the gun filament by pressing the GUL FIL 1 OFF button.

32. Turn off the high voltage by pressing the HV OFF button.

33. Shut down the CV-8 power supply with the breaker switch on the front of the supply.

34. Stop the sample rotation by setting the SAMPLE ROTATION switch to OFF.

35. Allow the source to cool for 4-5 minutes before opening. During this time, you can check the crystal sensor health (parameter 36) and make a new entry in the log file on the lab computer.

29. After the source has been allowed to cool, the system can be vented. Start the process by pushing the AUTOSTOP Temscal control panetl to start the venting sequence. You will hear the valve to the main cryopump close immediately. Turn off the filament to main chamber ion gauge. After a delay of several seconds, the nitrogen gas valve will open, and you will hear the system begin to vent.

30. The system will be vented after 2-3 minutes, and you will be able to open the lid to the chamber. Once the system is vented, you can stop the nitrogen flow (saves on nitrogen gas use) by setting the N2 vent auto/manual switch to manual.

31. Remove your samples. Place dummy wafers back into the empty spots of the three-inch sample holder.

32. Open the shutter by moving Shutter 1 switch to OPEN to reveal the source. Check the source, looking for anything unusual. Close the shutter by moving Shutter 1 switch to ATUO.

33. Replace the crystal if the final crystal health reading was below 50%.

34. Check the sealing surface on the lid. Remove any large particles using a clean room wiper.

35. Set the N2 vent manual/auto switch back to the auto position. Start the pumping-out process by pushing the AUTOSTART button. After a delay of 2-3 seconds, the valve to the mechanical pump will open and the system will start roughing down.

36. After 10-15 minutes, when the system pressure reaches 50 mTorr, the valve to the mechanical pump will close, and the valve to the cryopump will open. You should see the pressure drop rapidly. At this point, you can turn off the mechanical pump (breaker switch on front panel) and turn on the filament to the ion gauge.