Chapter 7.11

Lam6 Oxide Rainbow Etcher

1.0 Equipment Purpose

1.1 Lam6 is an automatic, cassette-to-cassette, plasma etcher (Rainbow 4520). This tool is currently dedicated to etching silicon oxide and nitride films. No metal etching or using a metal hard mask to etch other films are allowed in this tool. Lam6 operates under an upgraded GUI software, Envision®. This system is capable of etching sub-micron features with near vertical sidewalls and provides high selectivity over the underlying silicon with the over etch recipes. The robot is set up for 6-inch wafer. A 6-inch carrier wafer or a 6-inch pocket wafer can be used to process a 4-inch wafer or samples of other sizes (see Process Notes, Section 8.3, for details). The scope summarizes what is covered in this chapter.

1.2 This document describes the general operations of Lam6 oxide etcher machine, editing recipe, setting up graphs to monitor endpoint signals, and basic trouble shooting procedures are also covered here.

2.0 Material Controls & Compatibility

2.1 Substrate Restrictions

2.1.1 Lam6 is restricted to etching silicon oxide and silicon nitride films. Permission must be obtained from process engineer 1 to etch other materials in this tool.

2.1.2 Photoresist must be hard baked to enter lam6.

2.1.3 Glass substrates (including Pyrex) are not allowed in Lam6. This means deposited films on top of the glass substrate/s, as well as glass substrate itself, must not be etched in Lam6.

2.1.4 No metal film may be exposed to plasma at any point during your lam6 etch. All substrates bearing metal films must be reviewed by staff prior to etch, even if the metal is encapsulated with other layers.

2.2 Bonding restrictions

2.2.1 The only kapton tape allowed in Lam6 and/or any other etcher is 2345-1D, manufactured by Dupont.

2.2.2 Make sure that the glue residues from previous etch sessions are thoroughly cleaned, if you re-use a carrier wafer. Such residues could easily contaminate the etch chamber and severely impact consequent etch processes.

3.0 Applicable Documents

3.1 Rainbow 4520 Series System Operation, Envision, Lam Research, 1998

4.0 Definitions & Process Terminology

4.1 Rainbow 4520 Oxide Plasma Etcher: This type of plasma etcher uses a low frequency (400 kHz) RF generator that alternatively powers the top and bottom electrodes for better silicon oxide etch process.
4.2 **Automatic Endpoint Detector:** An optical device that traces the light emitted from the etch byproduct in the plasma. It can be programmed to end the etch process at a specified condition. Lam6 uses Channel A (520nm for silicon oxide) to monitor the amount of CO species.

4.3 **Etch Rate (ER):** The thickness of the film etched away, per unit time and usually in Å/minute.

4.4 **Etch Non-Uniformity:** A measure of the etch uniformity. NanoLab process monitoring sites define as (max ER – min ER)/ (average ER), usually in %.

4.5 **Isotropic/Anisotropic Etch:** An etch process that has the same ER in all directions is isotropic. An etch process that etches in the direction perpendicular to the substrate surface is anisotropic. A plasma etcher, e.g. Lam6 usually etches more anisotropically.

4.6 **Etch Anisotropy:** The degree of anisotropy is defined by \(1 - \frac{\text{lateral etch rate}}{\text{vertical etch rate}}\). A value of zero means isotropic etching and one is perfect anisotropic.

4.7 **Etch Selectivity:** The ratio of etch rates between the etched thin film (top layer) and the underlying substrate, if/when etched with the same recipe.

4.8 **Over-Etch:** An optional second etch step with etch chemistry that maximizes the etch selectivity. It removes the residual film due to previous etch non-uniformity with minimum damage to the underlying substrate/film. The etch rate is usually lower in this step.

4.9 **Pocket Wafer:** A six-inch wafer with a 4-inch pocket (recessed etched area), which enables one to load 4-inch wafer into a 6-inch process tool.

4.10 **Kapton Tape:** A special polyimide tape with silicon adhesive on it, which is good for high temperature application, and can withstand temperature range of –100ºF to + 500ºF.

4.11 **Control/Info Pages:** There are total of 9 control/info pages available on the Envision system. These pages can be selected by invoking the desired menu options (page buttons) available at the bottom of the screen.

4.12 **Operate Page:** Select recipe and start/stop wafer loading.

4.13 **Process Page:** Monitor wafer movement and etch chamber process parameters. Manually End-Point a process step, or abort the whole process.

4.14 **Recipe Page:** Write new recipe or edit existing recipe.

4.15 **Data Log Page:** Monitor endpoint signal traces.

4.16 **Alarm Page:** View and clear/purge alarms.

4.17 **Note:** Diagnose, Maintain, Setup, and Library pages can be viewed by users. Only Equipment staff is allowed to change the system setting on these pages.

**5.0 Safety**

5.1 **RF Power Hazard:** LAM6 uses a 400 kHz, 1250W RF power generators. Never touch a RF power cord when the RF power is on. Do not look at the plasma for a long period of time.

5.2 **Chemical Hazard:** All process gases used by LAM6 are confined in the gas delivery system and the vacuum chambers. However, if you smell bleach or other un-usual odor, stop the etch process and evacuate the area. Inform NanoLab staff immediately. There may be a leak in the system, or problem in the ventilation.

5.3 **Pinch Hazard:** The wafer cassette elevators may pinch your fingers. Load/unload wafer cassette with caution.
5.4 **Rule Applied to New Recipe or Modifying Existing Recipe**: It is required that you consult the process staff before creating a new recipe or modifying old ones. A recipe defined outside the machine specification may damage the tool and/or create potential hazardous situation.

6.0 **Process Data**

6.1 Quality Monitor data is available on MercuryWeb for 6001_OXIDE_ME

7.0 **Available Processes, Gases, Process Notes**

7.1 Available Processes

7.1.1 **Recipe 6001**: Anisotropic silicon oxide Etch. The same process parameters (steps) used for the Main Etch part (steps) of the 6003 recipe.

7.1.2 **Recipe 6002**: Silicon oxide etching can be accomplished with a high degree of selectivity over silicon/poly silicon with 6002 recipe. The same process parameter is used for the Over Etch part (steps) of the 6003 recipe.

7.1.3 **Recipe 6003**: A full oxide etching process with combination of Recipes 6001 and 6002. It starts with 6001 and stops when the automatic endpoint detector sensing the drop of CO species in the plasma. Then the process switches to 6002 for higher selective etching over silicon/poly-silicon.

7.1.4 **Recipe 6004**: Anisotropic silicon oxide etch with higher CF4/CHF3 ratio (4:1). It has slightly higher etch rate than 6001. The main advantage of this recipe is that the process produces less polymer. It is recommended for thicker silicon oxide layer.

7.2 Process Gases

7.2.1 **Ar**: Used in Poly-Si main etch for high etch rate.

7.2.2 **CF4**: Used for native oxide break through and oxide etch.

7.2.3 **CHF3**: Used with CF4 for oxide etch.

7.2.4 **He**: Used as diluent to improve etch uniformity. Also used in He Clamp to improve the wafer backside cooling.

7.2.5 **O2high**: can be used for chamber cleaning.

7.3 Process Notes

7.3.1 The over-etch step selectivity and length of time to clear main etch residue depends on the device designs. Lam6 users should test/customize their over-etch step to fit their own designs.

7.3.2 Lam6 uses a mechanical clamp, attached to the upper electrode, to secure the wafer on the lower electrode. Helium gas then flows on the backside of the wafer to cool it uniformly. **The backside of the wafer needs be smooth, free of particles and/or any etch patterns**. Otherwise, the excess leakage of helium from the backside of the wafer could create process pressure stabilization and helium clamp pressure stabilization and abort the process.

    Note: the lower electrode is domed .050” center to edge. When the wafer is clamped down, it is domed as well.

7.3.2.1 **Do not use Lam6 Dummies as carrier wafers for processing your 4-inch or smaller substrate in this tool. Use your own carrier wafers instead to**
prevent cross contamination. Clean your carrier wafers in Msink8 before reusing them to prevent cross contamination.

7.3.3 You can save a file name, e.g. a customized recipe on the Lam6 system hard drive for your future use or as a backup. Please note that the file name DOES NOT have the old 8-character limit imposed by the old DOS system, however, file name still can not contain any special character/s or space/s. Please start the file name with your login name followed by an underscore _, e.g. ferrari_oxideetch1. This will aid you find your file (recipe name) in the directory, much quicker and the job of administrating the tool much easier for the staff to manage.
8.0 Equipment Operation

8.1 Startup
8.1.1 Enable lam6 on Mercury.
8.1.2 Clear the alarm
   8.1.2.1 The header should read Load and Process Idle: Host: LOCAL, and the alarm status below should read All system normal.

8.2 Loading Wafers
8.2.1 Load wafers to be processed in a blue cassette and load the cassette onto the entrance indexer (left side).
   8.2.1.1 Never remove a cassette from the tool when the exit or entrance arms are in motion.
8.2.2 Make sure the H bar on the bottom of the cassette sits properly in the slot at the center of the indexer. The indexer will lower to the first wafer position of the cassette.
8.2.3 Lam6 has an automatic flat finder for alignment. Make sure the wafers seat all the way to the end of the slots, and the flat is not in contact with the cassette (this will misalign the wafer)
8.2.4 Load another blue cassette on the receiving indexer (right side). It will lower to the last empty slot position.
   8.2.4.1 If a cassette already loaded on the receiving indexer and it is in the up position, tilt it toward you about 30 degrees and then release. It will start lowering down.

8.3 Starting a run

8.4 Click [Operate] Page Button, the screen displays the Control Panel page (Figure 11.1).
   8.4.1 If not, click [Menu] Button on the right lower corner, and select Control Panel.
8.5 Click [Select Recipe] Button, and select the recipe you plan to use.
   8.5.1 Do not overwrite the standard recipes. See process notes above for standard naming scheme.
8.6 On the left side of the [Start] Button, make sure that Load and Process is selected (white bullet means selected; grey means not).
8.7 Click [Start] Button to start the etch process. The header line change from Load and Process Idle to Load and Process Active.
8.8 Click [Process] Page Button to monitor the wafer transport and etch process (Figure 11.2). If the screen does not display the Main Chamber Page, click [Menu] Button on the right lower corner, and select Main Chamber. During the etch process, you can select to perform the following tasks:
8.9 Click [Manual Endpoint] Button to skip to next recipe step.
   8.9.1 Note: End point can be monitored in Data Log page.
8.10 After the process is complete, and the last wafer is loaded into the receiving cassette, the receiving indexer will rise up. Wait till the indexer stop, and then remove the cassette to unload your wafers.
8.10.1 If not, make sure the robot arm has retracted, then tilt the cassette it toward you about 30 degrees and then release. It will start rising up.

8.11 Pausing a process

8.11.1 If you want to change the etch time or select a new recipe for the next and following wafers, click [Pause Transport] Button on the top left corner of the screen. The wafer in the main etch chamber will continue and complete its original process.

8.11.2 Click [Resume Transport] Button to resume processing the wafer paused in the load lock or load station.

8.12 Shutting Down

8.12.1 Remove your wafers from the exit cassette

8.12.2 Replace exit cassette

8.12.3 Disable lam6 on Mercury

8.13 Recipe Editing/Writing

8.13.1 Click [Recipe] Page Button to access the recipe editor page (Figure 11.3).

8.13.2 Below the header, there are two buttons: one for Module selection (only PM1 9400 available) and the other for Page selection. Make sure [Recipe] shows on the button. If not, Click the Button and select Recipe from the pull-down menu.

8.13.3 On the right hand side of the screen, there are 8 buttons for recipe file managements, e.g. copy, delete, and etc. It is recommended that you modify an existing recipe for your process, instead of writing new one from scratch.

8.13.4 Click [Open] Button to open an existing recipe, or click [New] Button to write a new recipe. If you are writing a new recipe, enter the recipe name in the Recipe field, and a line of description in the Comment field.

8.13.5 You can enter/edit the process variables in every process step. The basic variables use in the standard recipes are:

   8.13.5.1 Pressure – The minimum pressure depends on the total gas flow.
   8.13.5.2 Top RF - Upper electrode power.
   8.13.5.3 Bottom RF - Lower electrode power (not used).
   8.13.5.4 Gap – 1.1 cm for all standard recipes. Maximum is 1.5 cm for proper mechanical clamp to secure the wafer.
   8.13.5.5 Process Gas Flows – Only Ar, CF4, CHF3, are used for etch processes. (O2 is used for chamber cleaning, and He for uniform wafer backside cooling.)
   8.13.5.6 He Clamp – 4 Torr for all the recipes
   8.13.5.7 Completion – There are 6 options for this field.
   8.13.5.8 Stabl: If the process condition is stabilized within the time specified in the Time field below, the recipe advanced to next step. Otherwise, the recipe holds and the system alarms. You have to clear the alarm (Section 9.5) to continue.
   8.13.5.9 Time: The recipe step will run the whole length of time specified in the Time field below.
8.13.5.10 EndPt: The recipe step will run till the Endpoint condition specified in the Endpoint fields (explained at the end of this section) is reached. If the Endpoint condition is not reached within the time period specified in the Time field below, the system alarms. You have to clear the alarm (Section 9.5) to continue.

8.13.5.11 EndPt2: Not used.

8.13.5.12 OverEtch: The recipe step will run the percentage, specified in the Time field below, of the length of time of the previous EndPt step.

8.13.5.13 Recipe: This entry terminates the recipe. This process step and following steps will not be executed.

8.13.5.14 Time (sec): The maximum length of time the recipe step will run.

8.13.5.15 Note: Do not select Recipe Params from the pull-down menu. The Recipe parameter page set up the chamber temperature, the lower electrode temperature and other machine parameters. The chamber and lower electrode temperature are controlled by two separate chillers in the service area. If you need to change these temperatures, contact equipment staff.

8.13.6 The following values setup the Endpoint Trigger in the Main Etch Step (EndPt step)

8.13.6.1 Channel: The automatic Endpoint detector channel. Enter A for poly-silicon etch.

8.13.6.2 Delay: In this time period, the endpoint signal is ignored due to plasma stabilization, and etc.

8.13.6.3 Norm (sec): In this time period, the endpoint signal reading is normalized (averaged).

8.13.6.4 Norm Value: The system will shift the normalized endpoint signal reading to a number that is easy for calculation, e.g. 5000 in the standard recipes.

8.13.6.5 Trigger (%): If the endpoint signal falls below this percentage of the norm value, the recipe step ends and continue on next step.

8.13.6.6 Note: Do not select EndPoint2 from the pull-down menu since it is not used in Lam6.

8.14 Process variable tolerance set ups

8.14.1 There two types of tolerances can be set in a recipe: hard tolerance, and soft tolerance. If a process variable exceeds the hard tolerance, the system will alarm and the recipe step will abort and you have to clear the alarm (Section 9.5) to continue. If a process parameter exceeds the soft tolerance, the system will just alarm and continue. The default tolerance setting for all steps in a recipe is 10% for both soft and hard tolerance.

8.14.2 To change the tolerance of a process variable, click the [Recipe] button next to the work Page, and select [Recipe Tolrnc] from the pull-down menu. You can now change the variable tolerance of process variables.

8.14.3 It is recommended to increase tolerance of Pressure in the recipe step that plasma strikes. When the plasma strikes, the pressure jumps up a few mtorr for a very short of time. If the pressure was below 20 mtorr, the pressure increase will exceed the 10% hard tolerance.
8.14.4 Save the recipe to the hard drive by click [Save] Button on the right side of the screen. Do not over-write the standard recipes on the hard drive. If you are saving a modified standard recipe, click [Save As] Button. And save the recipe with the a new name that starts with you login name.

8.14.5 Note: Only the recipes saved on the hard drive can be selected on [Operate] page. If you have modified a recipe but have not saved it on the hard drive, you will be running the un-modified version of the recipe when you select it on [Operate] page.

8.15 Endpoint Signal Tracing

8.15.1 Click [Datalog] Page Button and the Graph Page shows on the screen (Figure 11.4). If not, Click [Menu] Button, then select Graph.

8.15.2 On the lower left corner of the Graph page, there are four signal channel fields, i.e. A, B, C and D, that you can select. Select a channel, then click [Load Config] Button below the field. A window with all the preset signal channel configurations will pop up. Select the signal, e.g. Endpoint Channel A, TCP RF, and etc. Do the same for other signal channels.

8.15.3 Click [Manual On] Button below the graph to start the signal tracing. The signal traces will show up when the recipe is running in the process chamber.

8.15.4 On the top and bottom of the Y axis, you can enter the range each tracing signal. Adjust the range according to you preference.

8.15.5 If you are satisfied with your set up and plan to use the same set up in the future, Click [Save Set] Button on the lower left corner. Save the set up with the name started with your login. In the future, you can load the same setup by clicking [Load Set] button, and then select the set up you saved.
9.0 Troubleshooting Guidelines

9.1 Alarms

9.1.1 Indicator Symbols – There are three types of alarm symbols with a brief message displayed in the second line of the header area of each page screen.

9.1.2 Green Circle: All system Normal.

9.1.3 Red Triangle: Indicates an emergency condition, process abort by user, or a process variable exceeding hard tolerance. Wafer transport suspended; and the alarm must be cleared by the user.

9.1.4 Yellow Square: Indicates a less severe condition. The wafer in the process chamber will either hold at a stabilization step, or complete the etch step. However, the wafer transport will be suspended until the alarm condition has been corrected and the alarm cleared itself.

9.2 Responding to an alarm

9.2.1 Click Operate. Click Stop loading wafers.

9.2.2 Click Alarm Page Button, the alarm status page will show up (Figure 11.5).

9.2.3 Check listed alarms for the various scenarios listed below.

9.2.4 If not any of the below scenarios, click Clear Alarm.

9.2.5 The wafer should return to the cassette and wafers should stop loading into the system.

9.2.6 If a wafer does not return to the cassette, report a problem on mercury.

9.3 System logged out:

9.3.1 Cause: Previous user logged out of system

9.3.2 Solution: Click [Security] Button (padlock icon) to open the User Login Window

9.3.2.1 Username: Super User

9.3.2.2 Password: secret

9.4 Wafer In The Entrance Cassette Not Picked Up By The Wafer Shuttle

9.4.1 Cause: The wafer cassette is not loaded properly.

9.4.2 Solution: Adjust the cassette slightly to correct the problem. Do not lift the cassette because the wafer shuttle is in the cassette.

9.4.3 Cause: The wafer is not loaded properly, e.g. cross slots, in the wafer cassette.

9.4.4 Solution: Report the problem on MERCURY, or ask help from the equipment staff. Do not try to remove wafer cassette or wafer from the cassette. Doing so may bend the wafer shuttle stuck in the cassette.

9.5 Load Point Vacuum Alarm

9.5.1 Cause: Wafer back side too rough or contaminate with particles/film.

9.5.2 Solution: Ask equipment staff to remove the wafer for you.

9.5.3 Cause: Wafer Shuttle vacuum problem
9.5.4 Solution: Wait a few seconds, this problem usually clears itself. If not, Report on MERCURY.

9.6 Chamber/Electrode Temperature Out of Tolerance Alarm

9.6.1 Cause: Previous user may set a different temperature.
9.6.2 Solution: Wait for a few minutes for the temperature to stabilize. If not stabilizing, report on MERCURY.
9.6.3 Cause: The chiller is not working. This is the case if the temperature is at or cooling toward room temperature.
9.6.4 Solution: Report the problem on MERCURY. The equipment staff will check the chiller.

9.7 Helium Clamp Pressure Stabilization Problem

9.7.1 Cause: The backside of the wafer is too rough, patterned, or contaminated with particles/film.
9.7.2 Solution: Abort the process run. Unload the wafer and check the backside. Try a clean dummy wafer with the same recipe. If problem repeats, see the following section.
9.7.3 Cause: The lower electrode surface was contaminated with particles, wafer chips, and/or films.
9.7.4 Solution: Report the problem on MERCURY.

9.7.5 Chamber Pressure Stabilization Problem

9.7.6 Cause: The total gas flow may exceeds the pump capacity (for customized recipe)
9.7.7 Solution: Reduce the gas flows or increase the process pressure setting in the customized recipe.
9.7.8 Cause: The Helium clamp flow too high. The clamp flow can be checked on the lower right side of Process Page.
9.7.9 Solution: same as the helium clamp pressure problem above.

9.8 RF Stabilization Problem

9.8.1 Cause: This is complex problem. It could be the process wafer, customized recipe, or equipment problem.
9.8.2 Solution: Abort the process and unload the wafer. Run a clean dummy wafer with a standard recipe. If problem repeats, report the problem on MERCURY.

9.9 Wafer Lost In The Chamber

9.9.1 Cause: Photo-resist on top of the wafer not properly hard-baked. Soft photo-resist sticks to the helium clamp after plasma heating. It may cause the whole wafer stick to the helium clamp and can not be unloaded.
9.9.2 Solution: Do not etch anymore wafers. Report the problem on MERCURY. Equipment staff will remove the wafer for you.
9.9.3 Cause: Wafer backside contaminated with photo-resist or sticky film. The wafer sticks to the lower electrode after the plasma heating. The wafer will be broken or pushed out of the position when unloading.
9.9.4 Solution: Do not etch anymore wafers. Report the problem on MERCURY. Equipment staff will remove the wafer for you. The wafer probably broke into pieces.

9.10 No Signal Trace or Signal Trace Doesn't Change (Horizontal Line) on Graph Page

9.10.1 Cause: Y axis Range not set properly.
9.10.2 Solution: Reset the Y axis Range.
9.10.3 Cause: Wrong signal channel selected.
9.10.4 Solution: Select the right channel.
9.10.5 Cause: Etch area on the wafer too small.
9.10.6 Solution: no solution to this problem.
9.10.7 Cause: Endpoint detector malfunction, or window dirty
9.10.8 Solution: Report the problem on MERCURY.
10.0 Figures & Schematics

Figure 11.1 - Envision Operate Page

Figure 11.2 - Envision Process Page (Main Chamber)
Figure 11.3 - Envision Recipe Page

Figure 11.4 - Envision Datalog Page (Endpoint Tracing)
Figure 11.5 - Envision Alarm Page
## Standard Recipes

### 12.1 Recipe 6001_OXIDE_ME: Standard Silicon-Oxide Main Etch

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### 12.2 Recipe 6002_OXIDE_OE: Standard Silicon-Oxide Over Etch

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### 12.3 Recipe 6003_OXIDE_ME_OE: Standard Silicon-Oxide Main Etch + Over Etch

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### 12.4 Recipe 6004_OXIDE_ME2: High CF4/CHF3 Ratio Silicon-Oxide Main Etch

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NanoLab Qualification Form

(Lam6 Oxide Rainbow Etcher)

(Lam6) (584)

Name ______________________  Office ______________________  Date ______________

Campus Phone __________________ Home Phone __________________

Login ______________________  Trainer ______________________

Qualification Test Passed (Signed by Front Desk) __________________

Oral Qualification Checklist

- Show how to login
- Show how to clear alarms after enabling
- Show how to load a recipe
- Show you know the standard process gases
- Show knowledge of how to set up an endpoint
- Show how to save a recipe
- Know how to warm up the chamber before your run
- Know how to manually endpoint
- Show operation of the indexers
- Define soft/hard tolerance, and yellow/red alarms.
- Know what pre-processing must be done to resist to be allowed in the chamber
- Know proper backside conditions of wafers entering lam6