Chapter 7.21

STS Poly / Si Etcher

(sts - 584)

1.0 Title

Surface Technology Systems (**STS**) Advanced Silicon Etch (**ASE**) system

2.0 Purpose

This document has specific information about the capabilities, configuration, and proper operation of the STS silicon etch tool

3.0 Scope

3.1 The STS multiplex tool is a manual wafer lock, low and high frequency **ICP** (Inductively Coupled Plasma) etch system. The **ASE** (Advanced Silicon Etch) process consists of alternating cycles of etching and protective polymer deposition to achieve high aspect ratios. The system can be used for deep Si trench etching of a single 6-inch (150 mm) substrate.

3.2 The process chamber is configured for deep Si trench etching. The plasma is inductively coupled at 13.56 MHz via a matching unit and coil assembly. Independent energy control is provided by a 13.56 MHz biasing of the electrode (platen) via automatic power control and impedance matching. Alternatively, for **SOI** wafer etching, a separate 380 kHz generator is available to bias the platen. The **SOI-RF** supply is pulsed via a pulsing generator. A high voltage electrostatic chuck secures the substrate within the process chamber during the ASE process. Cooling of the platen is provided by a DI (de-ionized) water chiller. Helium gas is used for aiding backside cooling of the substrate. Other gases configured with this system include SF_6 (Sulfur Hexafluoride), C_4F_8 (Octofluorocyclobutane), O_2 (Oxygen), and N_2 (Nitrogen). An aluminum load lock allows manual loading of the substrate to be processed.

3.3 SOI Upgrade

3.3.1 The **SOI** upgrade is a low frequency (LF) option used for etching Silicon to buried insulating layers. The **SOI LF** option is used to contend with the inherent variability in etch uniformity across the wafer (*bull's-eye effect*), the micro loading effect (RIE-lag), and the aspect ratio dependent etching effect (ARDE).

3.3.2 The **SOI** option works under the following principle: A separate pulsed, low frequency power input is applied to the platen during the etching cycle. This allows ions to escape more readily from deep trenches when the etching cycle is done. From this a decrease in over-etch sensitivity emerges, and the notching or "footing" of Silicon structures is minimized.

3.4 FTIR In Situ Depth Monitoring System

3.4.1 The FTIR system at STS is a unique and powerful instrument that is capable of measuring the precise depth of micro features *during* a DRIE process. The tool is also capable of measuring the thicknesses of multiple, thick film stacks that would otherwise be opaque to visible light. For more information on applications and operation of this system refer to Chapter 8.55

4.0 Applicable Documents

Revision History

4.1 **Mesc Multiplex Operators Manual,** issue 1, Silicon Technology Systems Limited.

4.2 **Process module 35 handle wafer (reversible bonding)**

4.3 **Conditioning Recipe Study (COND3)**

4.4 **Study: Effects from Oxygen Additive in Bosch Process**

5.0 Definitions, Process Terminology, Nomenclature

5.1 **ASE**: Advanced Silicon Etching

5.2 **DRIE**: Deep Reactive Ion Etching

5.3 **ICP**: Inductively Coupled Plasma

5.4 **SOI**: Silicon On Insulator

5.5 **Bull's eye effect**: phenomenon by which edges of wafer etch faster than central regions.

5.6 **Micro loading**: Phenomenon by which isolated trenches etch faster than those located in a dense array.

5.7 **Aspect Ratio Dependent Etch (ARDE)**: The occurrence of smaller features etching slower than those with larger dimensions.

5.8 Materials

If you have any special requirements/requests with regards to STS compatible materials, please discuss it with Matt Wasilik before running your process. There are special procedures to follow when processing materials other than the ones listed below. As of 02/09, the following materials are allowed in STS:

(1) Silicon
(2) photoresist (dispensed from 'svgcoat1, 2 or 3')
(3) thermal and LPCVD Oxide
(4) Silicon Nitride

Please Note: DO NOT attempt to purely etch Si Oxide or Si Nitride in the STS. Doing so will excessively contaminate the process chamber with by-products. In other words, ensure that a substantial area of Si or Poly-Si is accessible to be etched on your substrate.

5.9 Power Distribution

Both the prime power distribution (PPD) drawer and the power distribution panel are located at the top of the electronics cabinet (on the right hand side of the computer terminal). Unless there is an emergency situation, the circuit breaker switches should be left in the ON position (the default state) at all times.

5.10 Reflected Power

The power that is not being transferred to the load from the source (can take the form of heat). Ideally, the reflected power should be zero during a process, but may spike momentarily before the matchbox may properly tune.

5.11 Matchbox

Unit that contains a servo motor driven array of capacitors. This array adjusts automatically to maximize the power transfer from the source (power supply) to the load (plasma), ideally resulting in zero reflected power. The **STS** contains two matchboxes; one for the platen power (bias), and one for the coil power.

5.12 Autotuning: The process by which reflected power is automatically reduced to zero by means of a matchbox.

5.13 Peak to Peak Voltage: The voltage differential measured between the coil and platen at an instant in time.

5.14 DC Bias Voltage: The dc average voltage measured between the coil and platen.

5.15 Process Chamber Electronics

5.15.1 **Conductivity Monitor** – This module monitors the conductivity of the DI water supply that cools the platen. If the conductivity reaches a preset high value, a system interlock fault will occur.

5.15.2 **Interlock Display** - This monitors a sequence of electric and pneumatic processes inherent to the system. If there is a fault detected in the sequence, the RF power will be prevented from turning ON.

5.15.3 **Emergency Stop** - This button is located directly below the Interlock Display. It removes power to the entire system, and should be used only in an emergency situation. An emergency situation may be defined as a fire, flood, gas leak, earthquake, etc., or any other atypical event that is potentially harmful to the user or machine.

5.15.4 **HCL1** – This module monitors the process chamber lid temperature. Its setpoint and actual value should be 45ºC.

5.15.5 **ECUI** – This module contains the electrostatic chuck unit display. Its value should read **1600** when the substrate is being secured by electrostatic force.

5.15.6 **MKS 600 Series Pressure Controller** – This is located in the mid-section of the electronics cabinet. The value of the process chamber pressure may be viewed here. It should correspond roughly to the process chamber pressure value shown in the software's Machine View window.

5.15.7 **Pfeiffer Vacuum Display** - This controller is replaced with a Seiko Sei turbo controller. It has a new –temporary- location behind the FTIR controller box in the service area. The default display value corresponds to the turbo pump rev and should read 32000 rpm.

5.15.8 **HBCI Module** - This contains the helium backside cooling unit display. When the **ASE** process is running, the value of this display should read less than 3.00. A value higher than this indicates that the wafer may not be properly clamped on the electrostatic chuck. See Step 9.5.3 of Section 9.5 Running a Process, for the proper procedure to follow when the HBCI display value is greater than **3.00**.

5.16 RF Stack Components

5.16.1 **ENI VL 400 Phase Shift Controller** – This adjusts the phase of the platen and coil power such that the DC self bias is maximized. The Phase Shift Controller may be adjusted by lab staff personnel only.

5.16.2 **RFPP Electrode Power Supply** – This provides RF power (380 kHz) to the platen during an **SOI** etching process. It too should NOT be adjusted by users other than lab staff personnel.

5.16.3 **TGP 110 10 MHz Pulse Generator** – This box pulses the low frequency power from the RFPP supply. It will activate automatically only during an **SOI** etch process.

5.16.4 **ENI A-CG3 RF Electrode Power Supply** – This provides power to the platen during a standard 13.56 MHz **ASE** process. It may be adjusted by lab staff personnel only

5.16.5 **ENI A G-10B RF Coil Power Supply** – This provides power to the coil which in turn generates a plasma. Adjustments may be made by staff personnel only.

6.1 Safety

6.2 RF Power

This system, like many other dry etching systems, uses high-power radio-frequency (RF) energy to generate a plasma. Avoid disturbing machine cabling when loading or unloading wafers.

6.3 UV Radiation

Ultraviolet light is generated in the etch chamber during normal operation. As an added precaution, UV-blocking filters have been placed over the viewports in the chamber. It is not recommended to physically view the inside of the chamber. Use the FTIR's camera to view features on the wafer from the software instead

7.0 Statistical/Process Data

7.1 Link to http://microlab2.eecs.berkeley.edu/ProcessMonitor/index.html

8.0 Available Processes, Process Notes

8.1 Staff writes all STS process recipes. Ideas for new recipes and improvements to current recipes are encouraged. Please, consult with Matt Wasilik for more information.

Standard 25:1 Etching Process Recipe: HEXA100.SET

PARAMETER	PASSIVATION	ETCH
C_4F_8	85 sccm	0 sccm
SF_6	0 sccm	130 sccm
O_2*	0 sccm	13 sccm
RF Power (platen)	0 Watt	12 Watt
RF Power (coil)	600 Watt	600 Watt
Cycle Time	7.0 sec	9.0 sec
Over Run	0.5 sec	0.5 sec
APC:	66.0	
Process Time:	00:45:00.0	

* The addition of 10% oxygen helps prolong system pump life. It has been determined **not** to effect results of etch process (see Section 4.4).

9.0 Operation

The **STS** Multiplex System Operator Station software is a Microsoft Windows application. The software allows the user to load pre-existing process recipes, load and unload the substrate, run a process, and vent the load lock.

9.1 Operating Modes

The system is run in **STANDARD** mode. This operating mode allows the user to load, view, and run a pre-existing recipe. When re-booting the system software a password will be required to enter **STANDARD** mode. The following steps will only need to be performed when re-booting the software:

9.1.1 During the software re-boot process, an Operator mode dialog window will appear. Select **CHANGE** and **STANDARD**.

9.1.2 A dialog window will appear asking for the **STANDARD** mode password. Type the three letters “sta”.

9.1.3 A Confirmation window will ask the user to confirm the change. Select **CHANGE**. The software should now be configured to operate in **STANDARD** mode.

9.2 Software Operating Windows

9.2.1 **Process – Control ICP** - This window contains the brunt of **ASE** process display parameters. Gas flow rates, coil and platen parameters, etch/passivation cycles and other process status are contained within this window.

9.2.2 **Transfer** - This window allows the user to vent the load lock, and load or unload the substrate.

9.2.3 **ICP View** – This window displays process parameters related to the ICP process chamber.

9.2.4 **Machine View** – This window is a virtual display of the load lock and process chamber. The location of the substrate and position of the load lock lid and carriage assembly is also displayed here.

9.2.5 **Sequencer** – This window allows the user to run, hold, or abort a process.

9.3 Sample Preparation – Through-wafer Etching

9.3.1 Through-wafer etching (>300 microns) in **STS** requires a Si-Oxide encapsulated “handle” wafer. Due to the inherent etching of Silicon at the edges of a Si handle wafer, residue may be left behind in the process chamber when the substrate is unloaded. Oxide encapsulation of the handle wafer prevents this from occurring. Photoresist encapsulated handle wafers are disallowed in **STS**. Furthermore, Users should NEVER attempt to process a wafer in **STS** with resist facing down (touching the chuck).

9.3.2 Si-Oxide generally has a 100:1 selectivity (vs. Si). Handle wafers should be coated with enough oxide such that during the etch process in **STS** the handle will not be attacked excessively. Although the amount of Oxide on the handle wafer is to be determined by the User, be aware that:

***** RESIDUE LEFT WITHIN THE PROCESS CHAMBER DUE TO A POORLY DESIGNED HANDLE WAFER WILL BE GROUNDS FOR DISQUALIFICATION ON STS *****

9.3.3 Spun-on thick photoresist (9+ microns) used as a bonding agent has been found to promote charging between the handle and device wafer. This method of bonding is not recommended, as the wafer usually ends up stuck to the chuck in the process chamber. Users will be responsible for maladies inside the process chamber caused by improper handle wafer bonding. Users with unusual handle wafer processes are encouraged to consult engineering staff before attempting to process.

9.4 Sample Preparation - Handle Bonding

9.4.1 Substrates smaller than 6in diameter wafers may be processed in STS. Such substrates must be temporarily bonded to a 6 inch handle. See Process Module 35 (**http://microlab.berkeley.edu/labmanual/chap1/1.3.html#MOD35**) for instructions on how to perform a proper handle bond. Contact staff for further discussion.

9.5 Loading a Wafer

9.5.1 Ensure that **STS** is enabled on the WAND.

9.5.2 Ensure that there is no wafer present in the system by observing the software’s chamber schematic

9.5.3 If an **SOI** (low-frequency etch) recipe is to be used, see section on SOI etching below before continuing.

9.5.4 When not in use, the load lock should be left in a pump down state (100 mTorr or less). If this default state is encountered, first select the **STOP** button in the Sequencer dialog window. Then select the **VENT** button in the Transfer dialog window. The load lock will go through a series of purge and vent steps until it reaches atmospheric pressure.

9.5.5 Once the load lock has been vented to atmosphere, open the load lock door and manually place the wafer to be processed onto the spatula. Ensure that the wafer flat is positioned such that it is closest to the user, or likewise furthest from the process chamber. Align the flat as precisely as possible. Be careful not to bump the transfer arm.

9.5.6 Once the wafer has been placed on the “spatula” in the load lock, close the load lock door. Select the **OPEN** button in the Sequencer dialog window. Then highlight the sequence (recipe) that is desired to be run and select **OPEN**. The process is now ready to be run.

9.6 Running a Process

When the process chamber is in its pre-process or post-process state, the software’s Machine View window will show the **ICP** chamber area in the color BLUE. When the RF power is switched ON and a process is being run, the **ICP** chamber area will be displayed in the color MAGENTA.

9.6.1 Locate the Sequencer dialog window. Ensure that the desired sequence (recipe) is loaded (refer to 9.4.6. above). When ready, select the **RUN** button. The load lock will be pumped down to roughly 80 mTorr at which point the gate valve between the process chamber and load lock will open. The wafer will then be automatically transferred into the process chamber.

9.6.2 After the substrate has been loaded into the process chamber a gas stabilization time will occur. Then the RF will turn ON, and the etch / passivation cycles will begin. The dialog status should now indicate that the **ASE** process is running, and the **ICP** chamber in the Machine View window should be the color MAGENTA. The MAGENTA (pink) color indicates that a plasma has been struck.

9.6.3 Ensure that the HBCl display is less than 3.00. If the value is less than 3.00, continue with Step 9.5.4. If the value is greater than 3.00, the substrate may not be properly secured to the electrostatic chuck. If the substrate is potentially not centered on the chuck, DO NOT attempt to unload the wafer. Any attempt to unload under these conditions may result in a shattered wafer! Instead, select the **ABORT** button on the Process – Control window and report the fault on the WAND.

9.6.4 Ensure that the ECUI module reads roughly 1600. If this value deviates greatly from 1600 (e.g. 200 for instance) a fault should be reported on the WAND.

9.6.5 Ensure that the chamber lid temperature gage value is 45ºC.

9.6.6 Ensure that the recipe parameters displayed in the Process – Control window are correct (e.g. etch time, passivation time, platen power, etc).

9.7 Unloading a Wafer

When the substrate is finished being processed the following steps should be performed. Note that when the system is not in use, the load lock should be left in a pumped-down state.

9.7.1 Select the **ABORT** button from the Sequencer window. A confirmation window will appear asking the user to confirm. Select **ABORT** to confirm.

9.7.2 The option to unload should now be available in the Transfer window. First inspect the HBC1 reading. It should be less than 3.00. If the HBC1 gauge reads greater or equal to 3.00, do not attempt to unload the wafer and report an equipment fault instead. If however all is well select the **UNLOAD** button. The process chamber should purge and pump down. After this, the substrate will automatically be transferred to the load lock.

9.7.3 Once the substrate is in the load lock, select the **VENT** button in the Transfer window. The load lock will sequence through a series of vent and purge steps until it reaches atmospheric pressure.

9.7.4 When the pressure in the load lock becomes atmospheric, a prompt should indicate that the substrate may now be manually removed.

9.7.5 Open the load lock lid, and carefully remove the substrate from the spatula.

9.7.6 If another process is to be run, repeat loading process. If the system will not be used immediately, continue with the next step.

9.7.7 If the system will not be immediately used after processing, the load lock must be left in a pumped down state. Close the load lock lid (no wafer on spatula) and select the **STOP** button on the Sequencer dialog window.

9.7.8 Select the **RUN** button from the Sequencer window. Immediately after this, select the **ABORT** button and confirm the abort. The load lock will pump down to 80 mTorr, and remain at this pressure until further action is taken. Leaving the load lock in this low-pressure state will minimize contamination in the system.

9.8 SOI-LF Etching Directions

LF etching is essentially the same as HF (high frequency) etching. The only difference is that the platen is powered by a 380 kHz RF generator, and this frequency is actually switched on and off via a pulse generator.

9.8.1 Setting Signal on Pulsing Unit

9.8.1.1 The User will first want to ensure that the period of the pulsing unit is adjusted correctly. To do this, first ensure that no processes are currently running, then turn the oscilloscope power ON.

9.8.1.2 Ensure that the oscilloscope division resolution is set properly. The default settings are 5 ms per division, and 2 volts per division. Two signals will be measured on the oscilloscope: (1) the input signal from the pulsing generator and (2) the actual output signal from the RF power supply. Refer to **FIGURE 1** in section 11.0. Note due to an OEM hardware error, the actual pulsed signal sent to the platen does not match the desired signal set by the pulsing unit.

9.8.1.3 Although different recipes may require different pulsing, the default setting is a 20 ms period, with a 25% duty cycle. First adjust the pulse signal period if necessary using the knob on the TGP 110 10MHz Pulse Generator.

9.8.1.4 On the switch panel below the computer terminal, ensure that the operator key is turned to the LOCAL position.

9.8.1.5 On the same switch panel, ensure that the three switches are in the LF, HF CONTINUOUS and LF PULSE positions.

9.8.1.6 Load a dummy wafer into the chamber and start the LF process.

9.8.1.7 Monitor the actual pulsed signal during the etching cycle. This signal usually does not match the desired signal set by the pulsing unit. Adjust the desired signal pulsing such that the actual output signal is correct.

9.8.1.8 When the proper output pulse width (the duty cycle) is obtained, abort the process and unload the dummy wafer.

9.8.2 Running an LF Process

9.8.2.1 Ensure that the pulsing and period are set correctly (prior section). Load your wafer, and select a valid LF sequence.

9.8.2.2 Run the process.

9.8.2.3 When the process is complete, ensure that the HF/LF switch is set back to the default HF position.

10.0 Troubleshooting Guidelines

10.0 Software Bugs

The current version of the **STS** Operator Station software is known to occasionally lose communication with the hardware of the system. If the software "locks" and the Transfer dialog window yields no option for the user to select, the software must be re-booted as follows:

10.0.1 Select the EXIT menu from the **STS** Multiplex System Operator Station software.

10.0.2 A Confirmation window will ask the user to confirm the exit. Select EXIT again to confirm.

10.0.3 Select FILE and EXIT from the Windows desktop main menu.

10.0.4 After exiting Windows, a DOS command prompt will appear. Type the three letters "win" at the prompt. This will automatically restart Windows and reload the **STS** software.

10.0.5 In order to run a process, the software will now need to be set to the correct operating mode. Refer to Section 9.1, "Operating Modes".

11.0 Figures & Schematics

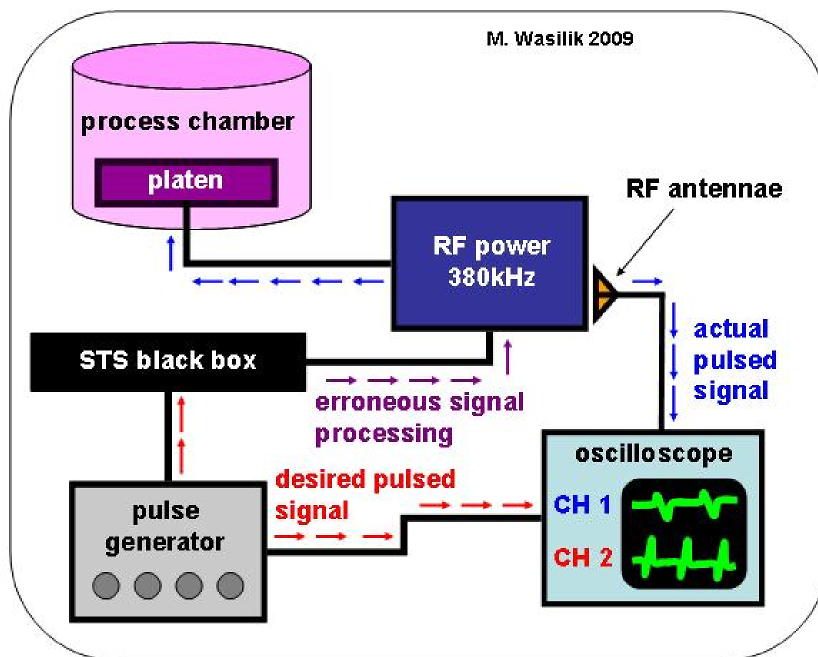

Figure 1

12.0 Qualification Procedures

Potential new users should arrange *ahead of time* to have an existing user review **STS** operation. Casual questioning (e.g. "Hey, can you review this with me for a moment?") is not to be considered an official review period.

12.1 The first question that should be asked is whether Chapter 7.21 - **STS** Poly-Si **ICP** Etcher of the WAND and the equipment header file have been thoroughly reviewed? If not, insist that it be reviewed before the meeting.

12.2 The "meeting" between the current and new user should be scheduled for enough time to explain equipment operation, load & unload sequence, execute dummy etch, review system errors etc. (I cannot see this taking less than 60 minutes as subtleties of the **ASE** process are sure to come up for discussion).Equipment time and dummy wafer can be recharged to new user's account if necessary.

12.3 The previous step should be performed at least twice by two different current users.

12.4 Upon successful completion of Step 11.4, new users should take the **STS** Users Test. Tests are administered by Microlab Office staff, and are graded by BSAC Engineering staff Estimate 2-3 days for grading. Satisfactory completion of this test will enable the user to meet with a Superuser for qualification.

12.5 Superusers will first ask, "Who trained you?" of the new user. "Training" implies adequately following Steps outlined above. The users identified as being the ones who did the training will be responsible for the information conveyed by the new user during the qualification.

12.6 Under no circumstances should a non-qualified User be allowed to operate STS without proper supervision.

STS Study Guide

Be sure to know...

1. How **ASE** differs from other etch processes.
2. Gases used by **STS**.
3. Materials and processes allowed in **STS**.
4. Possible masks and their selectivity.
5. Etch rates and parameters affecting them.
6. Etch rate non-uniformity.
7. RF supplies.
8. Wafer clamping, HBC reading and clamping problems.
9. Load lock.
10. Pressure controls, turbo pump speed.
11. Autotuning.
12. Displays and modules on the electrical cabinet.
13. If the process aborts.
14. Through wafer etching.
15. Wafer loading and unloading.
16. How to run a process.
17. Voltage – peak to peak
18. Voltage – dc bias