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Fabrication | Characterization | Expertise

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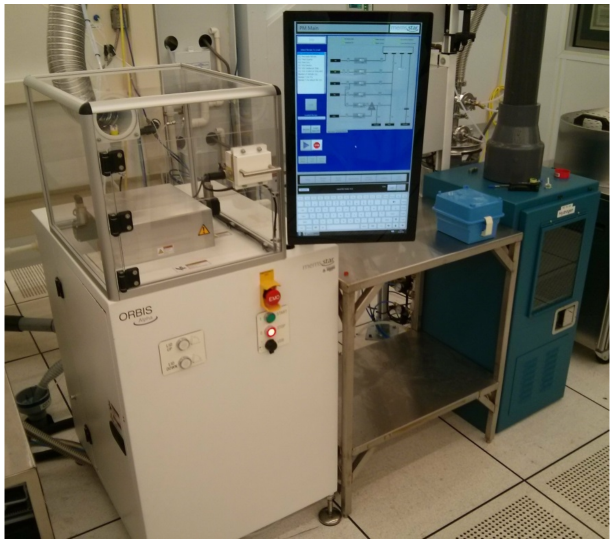
p: 780.492.0167 **www.nanofab.ualberta.ca**

Vapour HF Etcher (memsstar Orbis Alpha)

2017-01-18



Location: Cleanroom - Plasma Etch Area

Primary Trainer: Scott Munro
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OVERVIEW

The memsstar Orbis Alpha vapour HF etcher provides gas-phase (dry) etching of sacrificial oxides, enabling stiction-free release of devices for MEMS, Si photonics/optomechanics, and other applications which previously had to rely on HF-based wet etching followed by critical point drying. The *in situ* NDIR sensor allows for robust process monitoring and endpoint detection, for excellent run-to-run reproducibility.

The open-load system offers a universal chuck, enabling simple processing on a wide variety of sample sizes, from millimetre-sized pieces to full 200 mm wafers. The high degree of control over etch rates and selectivities between materials allows for unique process control. Backside N_2 gas is available for 100 mm and 150 mm wafers requiring backside protection of materials sensitive to HF.

SAFETY PRECAUTIONS

Compressed HF gas is used as the source gas. HF is a toxic, corrosive, oxidising gas. Several detectors are in place in and around the system, and the system is interlocked to prevent exposure. Do not operate of approach the area if there is an alarm (audible and/or visible).

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Silicon nitride films have been shown to form an ammonium fluoride (NH_4F) layer on the surface, typically during long etch times. This layer may be removed by heating the sample to 200 °C, which will sublimate the NH_4F, releasing NH_3 (ammonia) + HF gases. This step must be done in a fumehood, as both byproducts are hazardous.

Before bringing any new materials into the nanoFAB for processing, it is necessary to fill out a new chemical import request on LMACS.

PROCESS COMPONENTS AND FEATURES

Samples entering the chamber must be clean and dry. Samples may be any size and no mounting is necessary. Ensure the masking material is compatible with the etching process. Refer to supplementary documentation for a detailed list of compatible materials.

Photoresist is not compatible with the etching process due to the porosity of most resists to the HF vapour. The vapour will diffuse through the resist and etch the layer beneath the resist, creating a void or pressurised pocket. This may result in the material beneath the resist etching, and/or the void pressurising and bursting. This will likely contaminate other areas on the sample as well as the process chamber. For these reasons, photoresist should be avoided.

The overall reaction of HF and SiO_2 is described as: $SiO_2 + 4HF \rightarrow SiF_4 + 2H_2O$.

A catalyst is required to dissociate the HF; with the Orbis Alpha system, the catalyst is H_2O. H_2O is a controllable parameter within a recipe, and is also produced as an etch byproduct. The amount of water produced as a byproduct varies depending on the amount of exposed SiO_2, resulting in varying etch rates of standard etches across different mask designs. Unique recipes will likely be required for most devices and designs, and several samples may be required for process development.

An IR detector for real-time process monitoring is available, which detects the amount of SiF_4 generated by the etch. The detector and resulting spectra can be a very useful tool to indicate various points in a process, and when the etch is nearing completion. Smaller samples may have issues with low signals.

Refer to additional documentation for process trends and more detailed information. The following parameter effects table and compatibility table were taken from the memmstar presentation document *Alpha Oxide Full.pdf*.

Table 1:
Main parameter effects

Action	Etch rate	Uniformity
HF flow increase	Decrease	Increase
HF flow decrease	Increase	Decrease
H_2O flow increase	Increase	Decrease
H_2O flow decrease	Decrease	Increase
Pressure increase	Increase	Decrease
Pressure decrease	Decrease	Increase

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Material Compatibility with Vapour HF

Table 2:
Sacrificial oxides

Material	Comment
Thermal oxide	
SOI BOX	
Quartz	
PECVD (TEOS)	May form a residue (removed by anneal)
PECVD (silane)	May form a residue (removed by anneal)
Spin-on glass	Etches at low pressure
FSG	Etches at low pressure
BPSG, PSG, doped glass	Residue formed (not removed by anneal)

Table 3:
Structural materials

Material	Comment
Al	Will fluorinate slightly
AlF	
AlN	
Al_2O_3	Will fluorinate slightly
Au	
C	
Cr	
Cu	
Ge	
Ni	
Si	
SiC	
Si_xN_y (LPCVD, PECVD)	Forms residue (removed by anneal). Selectivity can be increased by making the film Si rich, and by using H_2-based processes.
TiN (bronze form)	
TiW	
W	

Table 4:
Incompatibility with vapour HF

Material	Comment
Photoresist	Porous to HF vapour
TiN (gold form)	Residue formed (not removed by anneal)
Ta_2O_3	Etches readily
Ti	Surface roughens, residue formed when part of a metal stack

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OPERATING PROCEDURE

1. On LMACS, login to tool *Vapour HF Etcher (memsstar Orbis Alpha); Location: Cleanroom*.
2. The software program should be running; if not, select the icon from the desktop. Login to the software using the username and password **O** (case sensitive).
3. While in the Main window, press the **Purge Vent** button to begin venting the process chamber. The system will cycle purge/vent 10 times prior to fully venting, and takes ~10 min to complete. Press **OK** when complete.

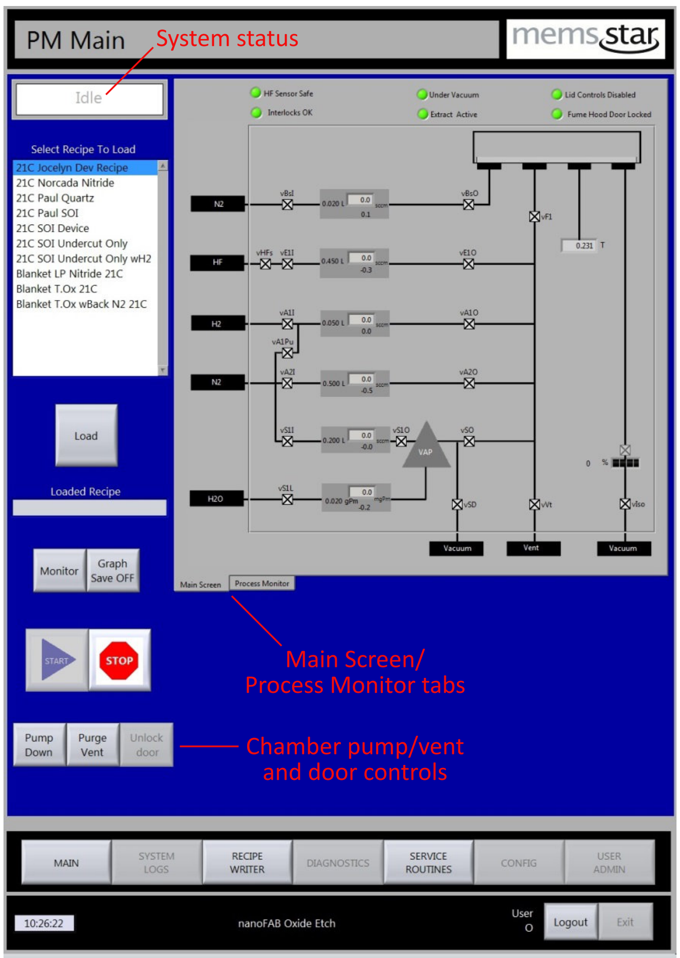

Figure 1: Main window

4. Once vented, the **Lid Up** button will light up on the front panel of the system. Press the button to open the chamber. Press **OK** on the software when prompted.

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5. Press **Unlock Door** on the software. The system will delay unlocking the door for 1 min while it monitors the enclosure for any residual HF. Wait until the door is unlocked after the 1 min delay—do not attempt to force the door open. Press **OK** on the software when prompted.

6. Once unlocked, open the door and load a sample. If required, the pins may be manually moved to a different position in the chuck. The standard position will be at 100 mm.

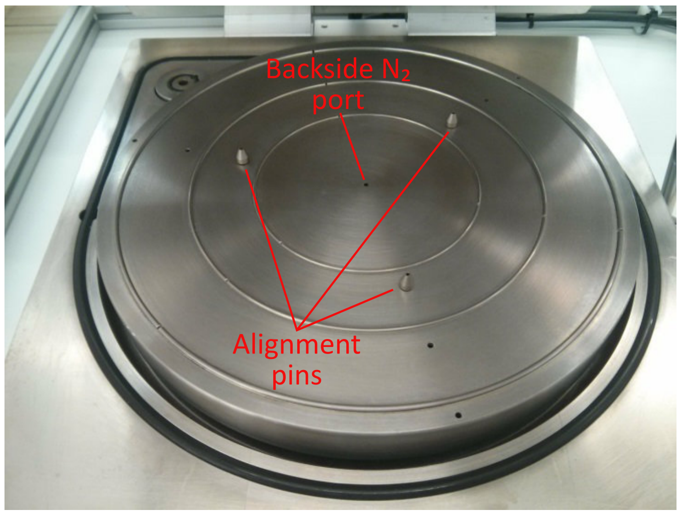

Figure 2: Sample chuck: single backside N_2 port and wafer pins

7. Ensure the sample is roughly centred within the pins. Close the door, and press **Lock Door**, followed by **Lid Down**. The door will lock and the lid will close.

8. Press **Pump Down**. The process chamber will evacuate and reach <100 mTorr in ~1 min. The pressure can be monitored in the **Main** page.

9. To view and make changes to a current recipe, select the **Recipe Writer** tab, and highlight a desired recipe. If making changes to any setting other than time, the recipe must be saved under a unique recipe name before the changes are made.

   Each recipe consists of a series of steps. Click the **«** or **»** buttons to view and edit individual steps. If changes are made, ensure that you press **Save Step and Recipe** before continuing to the next step.

   In general, a recipe will consist of the following steps:

   - Gases on (N_2, H_2O, HF, H_2, backside N_2)
   - Pressure ramp – With gases on, a pressure stabilisation step to 0.5 Torr less than the setpoint during the etch process.
   - Etch step – Beginning of the etch process, and typically labeled *Etch*. Options for ending are *Time*, *Manual*, or *Endpoint*. Edit the *End Value* row to adjust the time as required.

- Purge steps – The pressure is slowly decreased over a series of steps to protect sensitive devices from large pressure changes.
- Gases off and final pump – The process chamber is pumped to base pressure as the last step. When the system is vented, a series of N_2 purge and pump cycles will ensure no residual HF is remaining.

Backside N_2 may be used to protect the backside of a wafer from etching. This is only required for wafers with SiO_2 or other sensitive material on the backside. The N_2 will also not work with small pieces or samples that cannot be contained by the outer pins as they'll simply float off of the N_2 outlet port on the chuck.

H_2 may be added to improve selectivity between S_xN_y and SiO_2. The typical starting flow rate is 10 sccm, and can be added to an existing process as required. There will be minor changes to the process, and the process should again be performed on test samples. Selectivity will improve, with a likely side effect of a decrease in the oxide etch rate due to the increase in the HF:H_2O ratio (for fixed pressure).

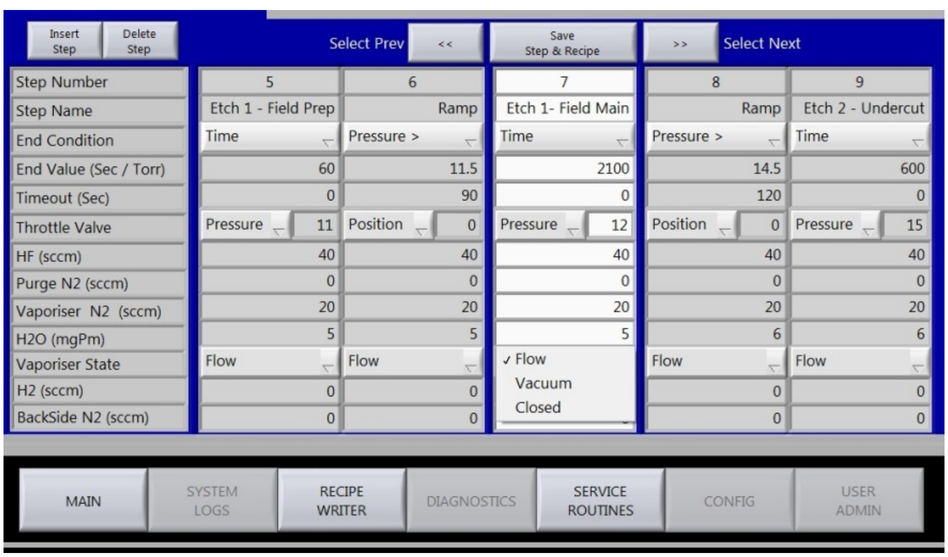

Figure 3: Standard Recipe Writer window

10. When all changes are made, return to the **Main** tab.
11. If graphical data is to be saved, ensure that **Graph Save ON** is displayed (rather than **Graph Save OFF**; click the button to toggle). This will save the numerical values from the Process Monitor.
12. Select the desired recipe, and click **Load**. When ready, click **Start**. The etching process will begin. The current step and time remaining in said step will be displayed during the run.
13. To view the signal during a process, select the **Process Monitor** tab. This may be used as a visual

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indicator to determine an endpoint.

14. The system will stop when the set time has been reached, an endpoint algorithm is reached, or it is manually stopped by the user. To stop the process manually, simply click the **Stop** button. There will be options to a) repeat last step, b) Continue to next step, or c) Abort.

    If using the Stop button to finish the recipe, it is recommended to select Continue to next step and allow the recipe to run to completion.

15. If the **Graph Save ON** button was toggled, you will be prompted to enter a folder name and a file-name for the graph. The folder name should be your name for ease of searching, and the filename should be something unique to the process. Note that the graph will only be saving counts vs. time, as seen in the process monitor, and is not a datalog file.

16. Vent the process chamber by again pressing the **Purge Vent** button. Press the **Lid Up** button when ready (button will be lit up), followed by the **Unlock Door** button. Wait until the one-minute timer is up before attempting to open the door.

17. Remove sample from the chuck. If etching is done, leave the chamber empty. If inspection is required before further etch, or another sample is to be etched, load now.

18. Press the **Lid Close** button. If performing further etches, return to Step 8. If etching is complete, the process chamber must be pumped out by pressing **Pump Down**.

19. Allow the chamber to reach base pressure. Note run information in the logbook. Logout of the software and LMACS.

TROUBLESHOOTING

The system contains several levels of alarms for detection of HF. If an audible or visible alarm is present, move away from the area around the tool and contact nanoFAB staff.

If you encounter an unexpected error or require assistance, please contact the primary or secondary trainer listed above. Should they not be available, please contact any staff member for assistance.

APPROVAL

Qualified Trainer: Scott Munro

Fabrication Group Manager: Aaron Hryciw

Version history
Scott Munro, 2016-10-24 (*memsstar HF Vapour Etcher SOP.docx*)