XeF2 dry etching

Some general comments

- Main use: isotropic and controlled chemical etching of Si on small samples with extreme selectivity to e.g. SiO2. It operates in 'pulsed' mode; applying pulses of XeF2 gas for typically 30s with a pressure of typically 1000-2000 mTorr (1 Torr is approximately 1.3 mbar).
- Warning: XeF2 is toxic and dangerous; read material safety data sheet before using it! Handle gently, and especially avoid any contact with water! XeF2 is a white powder, fumes are reactive, and it can react with water to form HF fumes: only handle in working and dry exhaust hood.

Description of etcher

- The **XeF2 powder** is contained in an short metal angled tube attached to the back of the etcher (on the outside). It has a **manual valve** to close it. Always keep this valve closed when the machine is not in use.
- Computer-controlled **valve 5** opens the XeF2 powder to the **pulsing chamber** (expansion chamber). This chamber can also be **vented with nitrogen** through computer-controlled **valve 4**.
- Computer-controlled **valve 3** lets XeF2 gas from the pulsing chamber into the **etching chamber** (sample chamber) in which the samples reside. This chamber is closed by a **glass lid** to allow for inspection of the samples during etching with the **microscope**. Over time, the glass will become 'foggy' due to reaction with produced gasses (notably HF by remaining water). It can to a large extent be cleaned off easily. The etching chamber can be **vented (purged) with nitrogen** through computer-controlled **valve 2**, and **evacuated** through computer-controlled **valve 1** in combination with a **manual valve (black knob on front)**. Note that the pump is only directly connected to the etching chamber. In order to evacuate the pulsing chamber, valve 3 must be additionally opened.
- The etcher is connected to a **nitrogen line**, and through a thick plastic tube to a **vacuum pump**, normally sitting in a separated room.
- Valves 1-5 are controlled by a computer (default) or manually. There is a small switch panel on the left of the front of the machine. The 'on' switch should be in the down position to operate, and the 'A' switch should be in the up position to allow computer control of the valves. If the 'A' switch is in the down position, the 5 switches on the bottom row control the valves.

- The software controlling the etcher is a labview script labeled '090123 - XeF2 etching.vi' on the desktop. The camera is accessed usin WinTV2000.

XeF2 etcher operation

1. We assume the machine is in standby mode (i.e., valves 1, 3, and 4 are open as well as the black knob on the front, such that both chambers are continuously being vented with nitrogen (entering the pulsing chamber) and evacuated through the etching chamber).
2. The valves can be controlled by clicking the 'LEDs' in the 'Valve Control' section of the vi. Stop venting (close valve 4) but keep valves 1 and 3 open, such that the pulsing chamber is evacuated to a low level (<~100 mTorr).
3. Open the manual XeF2 valve on the back of tool (green handle, 90° opening)
4. Open valve 5 to flow XeF2 all the way to the pump (valves 1 and 3 are open), and until pressure into the pulsing chamber stabilizes at ~3000 to ~4000mTorr (vapor pressure of XeF2 at Tamb).
5. Close valves 5 and 3. Keep valve 1 open for etching chamber to reach ~20mT.
6. Set the number of purge cycles in the 'Process Control' section of the vi. Typically, 30 pulses are sufficient, with purge duration 5 seconds, and pumping pressure 20 mTorr. Click the 'Purge' button at the bottom to start the automatic purging cycles.
7. When purge is finished, get valves 3 and 1 closed (if not already), and open valve 2 to vent the etching chamber. Unscrew the glass lid to avoid overpressure.
8. When the etching chamber is vented, open it and load your samples. Put samples close together, and position dummy samples around it to achieve more homogeneous etching. Note; the more samples inside, the slower the etch rate.
9. Close black knob (clockwise, in front of the process chamber) and close valve 2.
10. Close the etching chamber and screw secure the lid. Open valve 1 and SLOWLY open the black knob (counter-clockwise) on the front so the samples do not move. Monitor the etching chamber pressure: when smaller than ~5000 mTorr you can fully open the black knob.
11. Pump into etching chamber to base pressure (typically 20 mTorr).
12. Set the number of purge cycles you want to do in the 'Process Control' section of the vi (these are important to remove water, which will otherwise react to form HF!). Typically 30 pulses are sufficient, with purge duration 5 seconds, and pumping pressure 20 mTorr. Click the 'Purge' button at the bottom to start the automatic purging cycles.
13. When purging is finished, set the number of XeF2 pulses you want to do initially, their duration time (typically 30s), and etching pressure (typically 1000 mTorr for very slow etching but smoothest sidewalls). Click the 'Pulse Etch' button to start the automatic etching cycles.

14. Inspect your samples during etching in the microscope, and apply more pulses when necessary. Fill out the log sheet with the number of pulses you have applied. In case you want to stop prematurely, press the stop button of the vi (preferably during evacuation of the sample chamber), and press play again (white arrow on top), check that the necessary valves are closed and etching chamber is being evacuated. If you see that the pressure in the pulsing chamber is insufficient to reach the desired pressure in the etching chamber, the XeF2 has run out and you need to replace it (see below)
15. When etching is finished, purge again. Apply at least 35 purge cycles in order to clean the chamber before opening. Not applying sufficient purging will expose you to XeF2 fumes (noticeable as a 'chlorine' smell)!
16. After purging, check that valves 3,4,5 are closed, open valve 2 and close valve 1, close black knob on front (if you intend to keep some samples in), and unscrew loose the glass lid, to vent the etching chamber.
17. Remove your samples, close the lid again after you stop venting (valve 2), and pump the etching chamber (valve 1 + open black knob on front slowly if you still have some (dummy) samples inside).
18. After the etching chamber is pumped for some time, and if your session is ended, press the 'Standby' button in the bottom of the vi.
19. **CLOSE THE MANUAL XeF2 VALVE (**green handle, 90° opening) **ON THE BACK OF THE ETCHER**
20. Switch off lamp and monitor.

PS: Computer password is: 10tt10

User ID: highq