Hfvapor (Idonus HF VPE-100 / 150)
(hfvapor)

1.0 Title
hfvapor - Idonus HF VPE-100 / 150)

2.0 Purpose
The HF Vapor Phased Etching apparatus consists of a reaction chamber and a wafer holder. A heating element is integrated in the wafer holder. It controls the temperature of the substrate to be etched. Wafer clamping can be achieved in two ways: Wafers can be clamped mechanically using the clamping ring. The screwing is done from the backside of the apparatus, which is never in direct contact with the HF vapor. The three nuts are easy to handle with protection gloves. The other option is electrostatic clamping. Single chips (larger than 5 x 5 mm²) as well as wafers can be clamped to the heating element. A large area of the backside of the wafer is protected from etching. Liquid HF is filled into the reaction chamber. The reaction chamber is closed with the wafer holder. HF evaporates at room temperature and the etching process starts spontaneously. The etch rate is controlled by the wafer temperature that can be adjusted from 35°C to 60°C. After processing, the acid can be stored in the reservoir for reuse in a sealable container. Liquid transfer is simply done by lowering the reservoir.

3.0 Scope
Included in Section 2.0.

4.0 Applicable Documents

5.0 Definitions & Process Terminology
5.1 General Description
The VPE apparatus consists of a container, a wafer holder with connection cable, a controller box, and a mechanical clamping ring.
5.2 Container
The container is a system composed of a reaction chamber and a reservoir. The reservoir has the function to store HF acid when the HF VPE apparatus is not in operation and allows a simple and safe transfer of the acid in and out of the reaction chamber. The working principle of the reservoir and the container is called communicating vessels. When the reservoir is in high position, (i.e., the reservoir handle is pulled up) the liquid can flow into the reaction chamber (if the valve is open). If the reservoir is in low position, (i.e., reservoir handle is down) the liquid flows from the reaction chamber into the reservoir. The valve is open if the tap is vertical and closed if the tap is horizontal. The tap can be turned in both directions and does not have a stopper. Always cover the HF VPE apparatus with the lid if it is not in operation.

5.3 Wafer Holder
The wafer holder consists of a heating plate, a handle with connection cable, a mechanical clamp ring, and an electrostatic chuck. The connecting cable is waterproof if it is connected to the socket. The standard mechanical clamp ring is able to clamp 150 mm (6") wafers. The wafers are held by 6 clips. Three nuts fix the wafer mechanically to provide a good thermal contact to the heating plate (use only minimal torque then tightening these nuts to prevent breaking the clamp’s threaded studs). The electrostatic clamping is realized by an optional bipolar electrostatic chuck. The high voltage to drive the electrostatic chuck is created inside the wafer holder. Flat, conductive substrates can be clamped by the electrostatic chuck. Due to its design, a wafer as well as multiple chips can be clamped. The chips have to be placed in order to cross two electrodes. The wafer holder with electrostatic chuck is waterproof and can be rinsed with water. Do not rinse for more than 15 minutes.
5.4 Controller Box

The front side consists of main switch, temperature controller (see separate manual for the special functions of the temperature controller), socket for connection to wafer holder, and switch for electrostatic clamping. Potentiometer can adjust electrostatic clamping force.

Controller box backside has a socket for power supply and a fuse. The front panel of the controller box is spray water resistant. The controller box should not come in contact with any liquid. Spray water resistant mounting is achieved if the controller box is integrated into the workbench. The backside of the front panel has to be sealed to your workbench.

5.4.1 Operating the Temperature Controller

The display shows the process value.

5.4.1.1 Operating Level: The set point SP is input here. On active set point switching via the logic input, SP 1 or SP 2 appears in the display. When the ramp function is active, the ramp set point SPr is displayed. With activated timer function, the timer value t i or the timer start value t i 0 is shown. The set point is altered dynamically using the i and d keys. The setting will be accepted automatically after approx. 2 sec.

5.4.1.2 Parameter Level: The set points, the limit value of the limit comparator, the controller parameters and the ramp slope are programmed here.

5.4.1.3 Configuration Level: The basic functions of the controller are set here. In order to make the settings, it is necessary to change to the configuration level A via the parameter y:0 (parameter level).

5.4.1.4 Timer Level: The current timer value (only when the timer has been started) and the timer start value are altered here. The parameters at this level are marked with an underscore in the display.

5.4.1.5 Time-Out: If no operation occurs, the controller returns automatically to normal display after approx. 30 sec (exception: with timer functions starting via power ON, the timer value is displayed). If the timer value is displayed at the operating level, time-out is not active.

6.0 Safety

6.1 General Safety Instructions

6.1.1 Working at the hfvapor tool should be considered equivalent to working at one of the Microlab sinks. Therefore, as with all Microlab sink operations, lab members must wear acid resistant gloves, face shield and acid resistant apron when operating or servicing the hfvapor tool. Lab members should be especially attentive to residual HF acid from preceding etching processes, opening the reaction chamber during operation, condensation of HF acid on parts of the apparatus or the substrate.
6.1.2 If you encounter a spill at a sink of an unknown solution, first check the pH. The pH test strips can be found in plastic dispensers located at sink432C adjacent to hfvapor. Color charts with reading instructions are laminated and posted by these dispensers. The pH test strips are calibrated to read from 0-14 pH. If the spill solution is strongly acidic (or strongly basic), use a sink deck hose to flush the solution into the sink. If it is near neutral or you have finished flushing, use a Techni-cloth to wipe and dry the surface. When finished, rinse the Techni-cloth and dispose of it.

6.1.3 During operation of the apparatus HF acid evaporates at room temperature. Therefore, risks associated with the tool are associated with HF acid liquid and HF acid vapor. Exposure to HF acid vapor is minimized by housing the tool in a ventilated hood enclosure. All reservoir filling and emptying operations should be performed in this or one of the other exhausted sinks in the old lab to prevent any exposure to HF acid vapor.

6.1.4 HF burns are particularly hazardous. An insidious aspect of HF burns is that there may not be any discomfort until long after exposure. These burns are extremely serious and may result in tissue damage as fluoride ions diffuse through tissue. If you contact HF, flush the area well and be sure to work under and around your fingernails. Under fingernails and cuticles are the main areas people receive burns, having washed off the HF without washing under their nails. If washed off within a few minutes of exposure, HF will do no harm. Remember, HF may not produce any burning sensation until after it has already done damage. You should have a physician examine all HF burns.

6.2 First Aid for HF Burns to the Skin
6.2.1 Remove contaminated clothing.
6.2.2 Flush with cold water for 15 minutes.
   There is safety shower and eyewash immediately behind you when operating hfvapor.
   There is also immediate running water available at sink432C or the black utility sink across the room.
6.2.3 Gently massage calcium gluconate ointment into skin.
   There is a container of this material in the plastic dispenser mounted on the front of sink 432C.
6.2.4 Report any HF burns to the office during work hours or call Bob Hamilton at 644-3329.
6.2.5 Seek medical attention at Tang Center or Alta Bates. It is not necessary to call 911.

6.3 Electrostatic Chuck Damage and Safety Concerns
6.3.1 When the electrostatic chuck’s isolation layer or the chuck itself is damaged (cracked or shorted), do not operate the machine, as electrocution may occur. Turn off the main switch on the controller box, disconnect the chuck (handler) and report the fault on the wand.

7.0 Statistical/Process Data
N/A

8.0 Available Process, Gases, Process Notes
49% HF
Dish Temp 27ºC
Etch rate
45ºC: ~ 55/65 um/hr
50ºC: ~ 22 um/hr
55°C: ~ 16 um/hr
60°C and prebake (10 min at 180°C): ~ 8 um/hr

These figures are only a guideline. Actual etch rate will vary due to sample and prior process variations.

9.0 Operating Procedure
Etching and filling or emptying the reservoir must be done by a qualified user. If HF acid leakage is observed execute the following steps. Execute the steps with extreme care.

- Empty the container (see Section 9.3, Emptying Procedure)
- Rinse the container with water (see Section 9.4, Cleaning Procedure).
- Contact our technical support for assistance and repair.

9.1 Etching Procedure of Oxide
Before you start working with the apparatus make sure that the safety requirements are accomplished. Following, the etching procedure for thermal SiO2 is described.

9.1.1 Wear protective clothing, gloves and glasses
9.1.2 Make sure the reservoir is filled with HF. If not, ask the responsible person for service (SERVICE MODE).
9.1.3 Connect the connection cable of the wafer holder to the socket of the controller box.
9.1.4 Switch the main power switch of the controller box ON.
9.1.5 Program the temperature controller to the desired temperature.
To do this press the P button once and select the desired temperature with the ↑ and ↓ buttons. The selectable temperature range lies between 35 and 60°C (90°F to 140°F). Thermal SiO2 should be etched at temperatures around 40°C (104°F). Decreasing the temperature of the substrate increases the etch rate. If your etch rate is too slow decrease carefully the temperature.
9.1.6 Wait until the desired temperature is reached (1-5 min). The temperature of the heating plate is indicated on the temperature controller.
9.1.7 Place the mechanical clamping ring in front of you so that the bolts are facing upward.
9.1.8 Place your wafer on the ring so that the surface to be etched faces down.
9.1.9 Place the wafer holder over the clamping ring and fit the bolts into the holes of the wafer holder.
9.1.10 Use the three nuts to fix the clamping ring. Do not overturn the plastic screws. Overturning the screws may result in damage of the screws, the clamping ring or the wafer.
9.1.11 Electrostatic clamping can be used additionally to the clamping ring or alone. If wafers are clamped by electrostatic force only a minimal force is required. If a too high force is applied, the removal of the wafer can become critical due to residual fixed charges present in the dielectric isolation of the electrostatic chuck. These fixed charges disappear slowly without any further action.

Note: “DO NOT USE ADHESIVE MATERIAL/TAPES ON THE E-CHUCK.” Kapton tape and/or other material should not be used to hold samples/wafer on the chuck. This will damage the E-chuck. For small sample/s that cannot properly bridge the conductive path on the E-chuck, simply place it/them in kitty corners of the conductive path where it makes a few loops (sharp turns) confined to small areas.
9.1.12 Place the wafer holder in front of you so that the electrostatic chuck is facing upward.
9.1.13 Place your wafer or chip on the electrostatic chuck so that the surface to be etched is facing you.

**DO NOT USE METAL TWEEZERS OR OBjects TO REMOVE WAFER OR SAMPLES. USE ONLY TEFLOn OR PVDF TWEEZERS TO REMOVE WAFER OR SAMPLES.**
9.1.14 Switch the power for the electrostatic chuck to ON position. Adjust the force by turning the potentiometer.
9.1.15 Make sure your wafer is fixed.
9.1.16 Place the wafer holder on the reaction chamber with the wafer facing down.
9.1.17 Lift reservoir handle up.
9.1.18 Turn the security pin to fix the reservoir in high position.
9.1.19 Open the valve (tap vertical).
9.1.20 Start your timer. The etching process starts immediately.
9.1.21 30-40 seconds before the processing time is finished release the security pin and push down the reservoir handle to place reservoir in low position. Now the acid flows into the reservoir.
9.1.22 When the process time is finished, lift the wafer holder and place it besides the container with the wafer facing down. The wafer holder may be contaminated with condensed HF. Do not touch the wafer holder of any other parts that were in contact with the wafer holder.
9.1.23 Loosen the three nuts.
9.1.24 Lift carefully the wafer holder from the clamping ring. The wafer may stick to the holder and release whole you are handling the holder. Usually, the wafer releases within several seconds from the wafer holder.
9.1.25 Take the wafer off the clamping ring. Do not touch the wafer. If the SiO2 is etched at too low temperatures HF may condense on the wafer surface. If any other material is present on the wafer, HF may diffuse in the material or react with it forming another dangerous chemical.
9.1.26 Releasing the wafer after usage of the electrostatic clamping. Place the wafer holder so that the wafer is facing you and switch OFF the electrostatic clamp.
9.1.27 Take the wafer off the heating plate. Do not touch the wafer holder; it may be contaminated with HF. Use soft tweezers, which do not scratch the dielectric layer isolating the electrodes of the electrostatic chuck! Rinse the tweezers after usage.
9.1.28 Close the valve (tap horizontal) after the HF acid has flown into the reservoir.
9.1.29 Close the reaction chamber by placing the lid onto the reaction chamber.
9.1.30 Rinse the wafer holder, clamping ring and bolts with water and dry them after rinsing.
9.1.31 Switch OFF the controller box.

9.2 Filling Procedure of the Reservoir

SERVICE MODE operations mainly cover the filling and exchange of the HF acid, the cleaning and maintenance of the HF VPE apparatus.

9.2.1 Wear protective clothing, gloves and glasses.
9.2.2 Make sure the reservoir is empty by lifting the handle into high position and open the valve. Secure the reservoir using the security pin.
9.2.3 Open the lid. Condensed HF may be present on the lid. Do not touch the lid or any other surface coming in contact with the lid. Rinse the eventually contaminated surfaced with water after filling the reservoir.
9.2.4 If the reaction chamber is filled with HF acid refer to Emptying Procedure of the Reservoir. Carefully fill the HF acid into the reaction chamber. Do not overfill! The HF acid level should be about 5 mm under the border of the reaction chamber (see following figure). In case of an overflow, pump the excess acid using a HF resistant pump. Should any acid drip besides the container, refer to the section.

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DO NOT USE METAL TWEEZERS OR OBJECTS TO REMOVE WAFER OR SAMPLES.
USE ONLY TEFLOÈN OR PVDF TWEEZERS TO REMOVE WAFER OR SAMPLES.
9.2.5 Put the reservoir into low position by releasing the pin and pushing down the handle. The acid flows into the reservoir. If it does not flow move the handle up and down a few times. If it still does not flow a slight vacuum, applied to the gas exhaust, helps to fill the reservoir for the first time. E.g. a pipette pump is sufficient to run this process. Release the vacuum right after the acid starts flowing.

9.2.6 Close the valve after all acid has flown into the reservoir (tap in horizontal position).

9.2.7 Close the reaction chamber with the lid.

9.2.8 Indicate that the reservoir is filled and ready for use.

9.3 Emptying Procedure of the Reservoir

Emptying of the reservoir is necessary if the HF acid is used many times or contaminated. Typically the HF acid can be reused for 10 to 100 etching processes, depending on the etching duration of the individual etchings. If you want to remove the HF VPE apparatus from your wet bench you need to have it serviced, the emptying procedure must be followed by the Cleaning Procedure described in the next section.

9.3.1 Wear protective clothing, gloves and glasses.

9.3.2 Lift the handle into high position and open the valve. Secure the reservoir using the security pin.

9.3.3 Open the lid. Condensed HF may be present on the lid. Do not touch the lid or any other surface coming in contact with the lid. Rinse the eventually contaminated surfaced with water after filling the reservoir.

9.3.4 Use a HF resistant pump to evacuate the HF acid out of the reaction chamber into your HF waste container.

9.3.5 Close the valve and cover the reaction chamber by the lid.

DO NOT USE METAL TWEEZERS OR OBJETS TO REMOVE WAFER OR SAMPLES.
USE ONLY TEFLOM OR PVDF TWEEZERS TO REMOVE WAFER OR SAMPLES.
9.4 Cleaning Procedure

Cleaning the container is done after emptying the reservoir. The reservoir, all tubing and reaction chamber can be rinsed with water through the rinsing hose. A connecting tube is delivered with the HF VPE apparatus. You need to connect the rinsing hose to your water supply. Use only moderate pressures below 0.5 bar to rinse the HF VPE apparatus! Higher pressures can harm the apparatus or eject diluted HF acid in vertical direction and causing HF burns.

9.4.1 Screw connection tube into hole beside the reaction chamber.
9.4.2 Connect the connection tube with the rinsing hose on the HF VPE apparatus.
9.4.3 Connect the other side of the connection tube with your water supply.
9.4.4 Tilt the container in a washbasin or use your laboratory pump to suck out the water from the reaction chamber (see following figures).
9.4.5 Rinse the container with water for at least 30 minutes.

9.5 Cleaning or Replacing the Net

If the net at the bottom of the reservoir is dirty or broken it has to be taken out for cleaning or replacement. The net is only fixed in a slot and due to the bigger size of the net. It can be lifted by taking it with fine tweezers and then bend it.

Note: Remove the net only after Cleaning Procedure of the container. Rinse net with water until it is clean or if it is broken replace it. To fit the net in, place a side in the slot and press it in.

10.0 Regular Service & Troubleshooting Guidelines

10.1 Regular Service

The following list is an overview about regular services, which must be executed by a Microlab staff.

DO NOT USE METAL TWEEZERS OR OBJETS TO REMOVE WAFER OR SAMPLES.
USE ONLY TEFILON OR PVDF TWEEZERS TO REMOVE WAFER OR SAMPLES.
10.2 Troubleshooting

If you have any difficulties operating the device please report to FAULT. The list below is should be carried out in SERVICE MODE by a qualified user.

<table>
<thead>
<tr>
<th>Problem description</th>
<th>Reason</th>
<th>Solution</th>
</tr>
</thead>
</table>
| Handle is in high position and no acid flows into reaction chamber | - Valve closed  
- No acid in reservoir  
- Tubing blocked | - Open valve  
- Fill reservoir  
- Move reservoir handle up and down several times. |
| No power to controller box | - Supply cable not connected  
- Broken fuse | - Connect supply  
- Replace Fuse  
1 A for 230V AC  
2.5 A for 110V AC |
| Error on temperature controller display | Cable between controller box and wafer holder not properly connected | Connect cable between controller box and wafer holder. |
| Acid does not flow from reaction chamber into reservoir | - Handle not in low position  
- Valve closed  
- First filling  
- Overfilled | - Put handle in low position  
- Open valve  
- Apply a slight vacuum (e.g. with a pipette pump) to the hole of the gas exhaust. Use connection tube with a hose to connect to the vacuum source  
- Use HF resistant pump to pump out the excess acid |
| Non-homogeneous etching | - Humidity on the wafer surface  
- Bad thermal connection between wafer and chuck | - Dehydrate the wafer in the oven (e.g. 1h @ 80°C) prior to etching  
- Make sure heating plate and backside of the wafer is clean and flat |
| Chip does not clamp to electrostatic chuck | - Clamping force too low  
- Bad clamping due to humidity on the chuck | - Increase clamping force with force adjustment button  
- Heat the chuck to 60°C for 1hr to reduce humidity on the chuck |
11.0 **Figures & Schematics**
N/A

12.0 **Appendices**

12.1 **List of Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF VPE</td>
<td>HF Vapor Phased Etching</td>
</tr>
<tr>
<td>SP</td>
<td>Set Point</td>
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</table>

12.2 **PID parameter Values after optimization at 40°C on 3/11/06**

<table>
<thead>
<tr>
<th>PID Parameter</th>
<th>Settings</th>
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<td>df</td>
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</tr>
</tbody>
</table>

**Note:** PID parameter values will change after optimization.

13.0 **Supplemental Notes**

The reactions involved in the vapor phase etch of SiO₂ are described by the following equations:

\[
2HF + H_2O \leftrightarrow H_3O^+ + HF_2^- \quad (1)
\]

\[
SiO_2 + 2H_3O^+ + 2HF_2^- \leftrightarrow SiF_4 + 4H_2O \quad (2)
\]

\[
3HF_2^- + SiO_2 + 3H_3O^+ \leftrightarrow H_2SiF_6 + 5H_2O \quad (3)
\]

\[
H_2SiF_6 \rightarrow 2HF + SiF_4 \quad (4)
\]

The first equation is thought to be the initial catalyzing reaction in which water is required, reactions 2-4 are then self catalyzed after the first reaction takes place [1,2,3]. The vapor HF manual from the vendor suggests drying samples thoroughly before etching the oxide films. The water needed to initiate the etch is scavenged from the ambient since the etch “chamber” is not isolated from the ambient air in the lab when the sample is placed on top of the HF reservoir. **IF samples are not dried before the vapor etch, the etch will proceed as if the sample is submerged in HF that is to say the process is no longer dry (capillaries will result killing any hopes of free standing structures).** The vendor claims the initialization time is roughly 10 min after which the etch rate stabilizes remaining roughly constant at the given temperature of the sample.

The water concentration at the oxide surface is controlled by the temperature of the sample. As shown earlier water is a byproduct of the vapor HF etch. The water that is created during the etch allows the oxide etch to continue, however if the sample temperature is high (above 40°C) more water is lost from the surface slowing down the etch rate. **From Transactions.** The dry etch process also depends on
the partial pressures of HF and water present in the vapor. In low concentration liquid HF sources the vapor pressure of HF is small so the fraction of HF in the liquid reservoir is much larger than the fraction of HF in the vapor [3]. For a high concentration HF reservoir the opposite is true (the fraction of HF in the vapor is higher than in the liquid reservoir such as the case for 49% HF) [3]. In 39% wt. HF the fraction of HF in the vapor and in the liquid reservoir is roughly equal [3].

Etching PSG in the HF vapor tool occurs relatively fast at all sample temperatures since it absorbs a lot of ambient moisture. The vendor recommends etching thermally grown (wet and dry) SiO₂ at 40ºC. At higher temperatures the etch rate substantially decreases for thermal oxides. CVD oxides etch faster than thermal oxides and native oxides etch faster than CVD oxides but slower than PSGs. The more moisture present at the surface of the sample decreases the relative selectivities [1].