RIE

This document is the reference usage procedure for Reactive Ion Etching (RIE) facility, and contains also vacuum and lines sketches. It does NOT substitute the documentation and the training, but it's intended as a quick reference for day-to-day operation.

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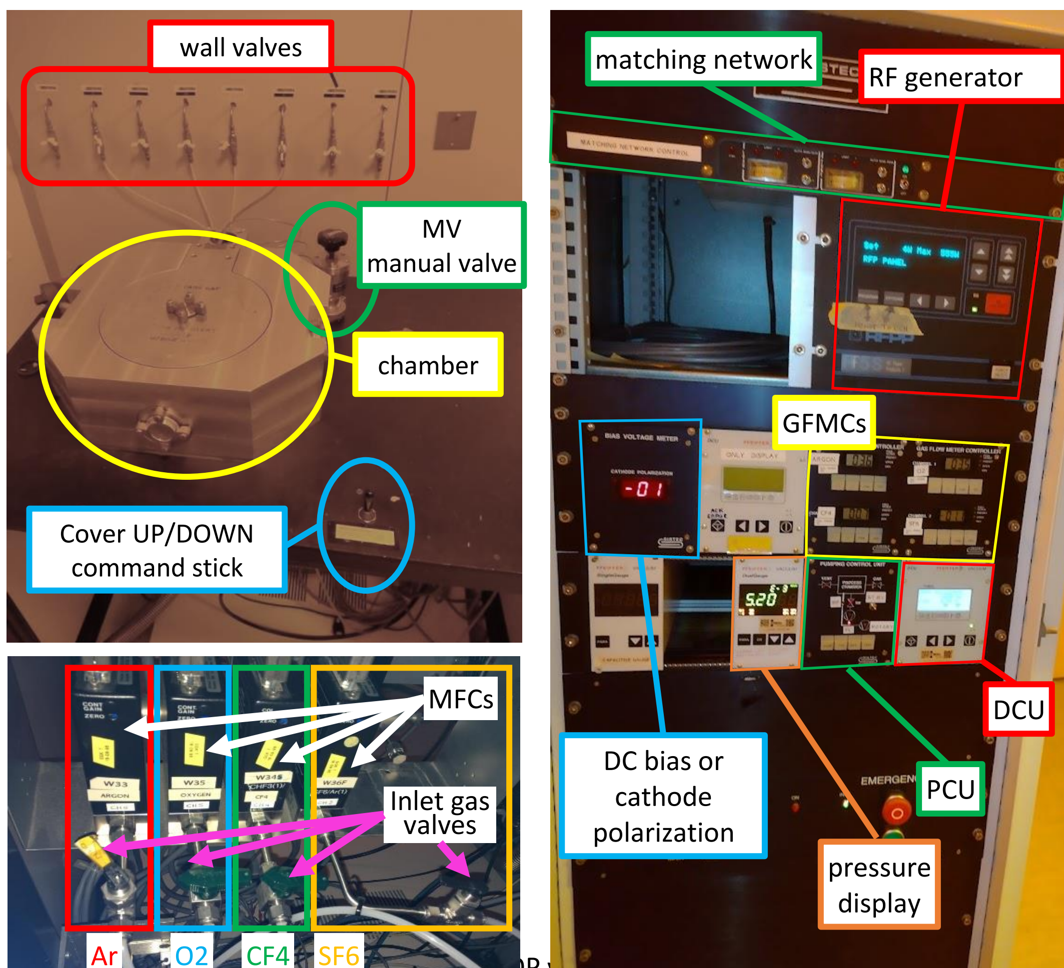

Standard operating procedure

The facility has to be booked prior to use. If for any reason the user will not use the facility during the booked slot, the booking must be cancelled.

The standby condition is:

- All manual inlet gas valves closed
- All MFCs closed
- Camber in HV condition:
  - Turbo at full speed
  - FL & HV valves open
  - Reading from the capacitance gauge (Ch1) in the mid-low E-5 mbar
- RF generator off
- Matching network off

To mount the sample:

- Vent the chamber:
  - Press the PUMP button in the PCU
  - Wait for the HV valve to close
  - Press the VENT button on the PCU
  - Wait for the chamber pressure to reach athmospheric pressure; it takes a couple of minutes. You can try lifting the cover of the chamber via the joystick to test if the chamber is vented.
  - When the chamber is vented, press VENT again to stop the N2 flow.
- Lift the chamber cover and turn it on a side
- Mount the sample(s) in the central part of the sample platen. Always wear clean gloves. Do not use adhesives nor clamps, make sure samples' bottom is clean so not to leave residues on the platen. Careful not to have samples or debris fall in the gap between the platen and the chamber bottom.
- Close the cover, lowering it until it's flat. Do not overlower it, else the o-ring wil not hold the vacuum.

Pumping:

- Press PUMP on the PCU
- The automatic vacuum cycle will take place:
  - FL closes and BP opens, starting to prepump the chamber with the rotary. While this is happening, the turbo is not backed by any pump. If the pressure at the back of the turbo raises above 3E-1 mbar (SP2 HI), the PCU will close the BP, and open the FL again. This is not normal, and it's an indication that pre-pumping is taking too long (i.e., the cover is not properly closed), or the rotary has problems, or there's a leak in the HV gate valve.
  - Upon reaching a pressure of 5E-2 mbar (SP1 LO), the BP is closed, the FL is open and finally the HV is open. At this point the vacuum will drop fairly fast, and in a few minutes the process can be started

Process:

- Adjust gas flow and process pressure
  - Open the bottle(s) of the process gas(es)
  - Open the manual inlet valve of the process gas(es)
  - Push THROTTLE in the PCU; the HV gate valve will be closed and a lower conductance valve is open between the turbo and the chamber. The HV LED flashes when in this condition.

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  - Push GAS in the PCU: the main gas valve (GAS) opens
  - Adjust the gas flow from the GFMC:
    - Push SEL until the "PRESET" LED is lit
    - Adjust the flow set point with "V" and "^"
    - Push SEL until the "OPEN" LED is lit
    - Push the "^" button to start the gas flow
    - The display shows the measured gas flow
    - Until the measured gas flow is not near the set point, the "DEV" LED is lit
    - By pressing SEL repeatedly one can go to SEL and adjust the set point even while gas is flowing
  - Wait for the capacitance gauge reading to stabilize to the desired process pressure.
  - The pressure can be regulated at fixed gas flow, by opening and closing the manual valve MV, thus changing the pumping line impedance
- Set RF power
  - Switch matching network on
    - Make sure both Load and Tune variable condensers controls in the matching network are set to AUTO
  - Switch RF generator on via the pushbutton
  - Set the desired process power ("Set") with the "^" and "v" keys ("^^" and "vv" change in 20W steps)
- Start the process
  - Start RF by pushing RF ON/OFF
  - RF display shows now "Fwd" (forward) and "Ref" (reflected) powers.
  - Make sure that reflected RF power ("Ref") is 0W or 1W maximum (high reflected power will dissipate in unexpected parts of the circuit potentially damaging the generator, the line or the matching network). If not stop the process and contact an experienced user to assess the problem and work on a solution.
  - Write down the critical process parameters:
    - Actual gas flow
    - Process pressure (from the capacitance gauge)
    - RF power
    - RF BIAS
    - Reflected power
- End the process
  - After your desired process time, stop the RF by pushing RF ON/OFF
  - Close the manual inlet gas valve(s)
  - Wait for the line to be pumped
    - The line is empty when the GFMC reading drops to near-zero (which is which is ~3 SCCM)
    - To speed up the process you can increase the GFMC set point
    - To speed up the process you can open the MV
  - Close the main gas valve by pushing GAS in the PCU
    - The GAS LED goes off
  - Go back to high vacuum by pushing THR in the PCU
    - The HV LED stops flashing and after a while the gate valve opening can be heard hand the LED turns on
  - Pump for a couple of minutes to make sure process gas and reaction byproducts are removed from the process chamber
- Dismount the sample

  - Vent the chamber as indicated above
  - Remove your sample
  - Close the chamber and push PUMP in the DCU as described before

Check out from the machine

- Switch OFF both RF generator and matching network
- Make sure all manual gas valves are closed
- Clean up the workplace
- Shorten your booking if you finished early

RIE process parameters

In order of importance they are:

- Process gas(es)
  - Obviously affecting the process
- Process time
  - Fairly obvious: most etchings are linear with time
  - Nonlinearities can be due to: the initial part of the etching being slower or faster (more complex surface chemistries due to adsorbates or oxides); etching slowing down in deep trenches (later stage of etching) due to slower diffusion of the ions in the trench or of the byproducts out of it; last but not least, byproducts could be non-volatile and accumulate at the etch front slowing it down.
- RF power
  - The higher the power the higher the ion density, and thus both the "chemical" and "physical" effect
- DC BIAS, or Cathode Polarization
  - The higher the polarization, the higher the kinetic energy of the ions hitting the sample -> higher "physical" action of the plasma, and higher directionality of the plasma (more anisotropic erosion)
  - DC bias is not directly tunable, and will depend mainly on process pressure and RF power. By playing with the two, one can tune the etching to be, i.e., more or less anisotropic, but there's not huge margin
- Process pressure
  - The lower the pressure and the lower the plasma density (slower etching) but also the longer the ions mean free paths -> more directional etching (more anisotropic)
- Gas flow
  - It has mainly an indirect effect on process pressure, which is the important parameter.
  - The flow must be sufficient to provide fresh ions to the plasma, and remove the etching byproducts from the gas phase; the flow must not be too high to avoid useless strain to the turbo pump

Available gases

Ar

Inert gas, and cheap for its fairly large atomic mass. It's mainly used to add some "physical", "sputtering-like" action to the etching, especially to remove non-volatile reaction products that would accumulate on the etching front, or to physically etch layers for which the chemistry is not suited.

O2

Oxygen plasma is very effective in removing carbon compounds, by forming volatile CO and CO2.

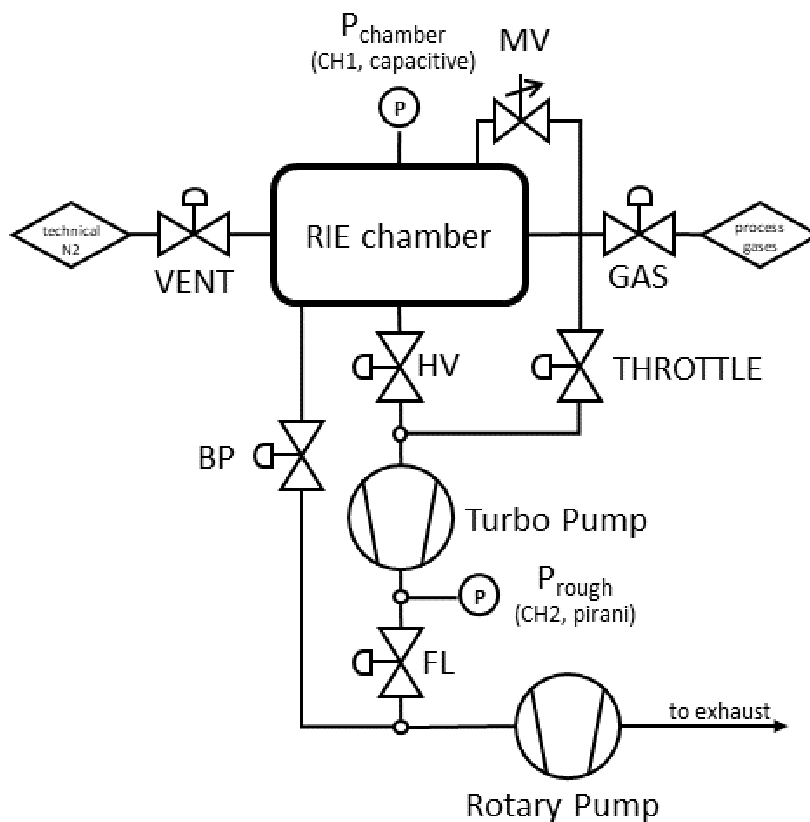
CF4 & SF6

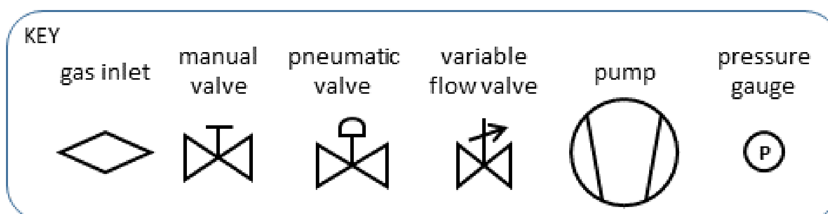
Both very effective to etch Si and SiO2, in recipes where they are mixed with Ar and/or O2.

Vacuum schematics

All valves depicted are actuated via the PCU interface, except the manual valve MV, which is manually opened and closed to adjust the pumping impedance and regulate the process pressure.

All valves are diaphragm valves except the HV which is a large gate valve.





Gauges set points and PCU reactions

The pressure display monitors 2 gauges and has 4 independent set points, although not all are used.

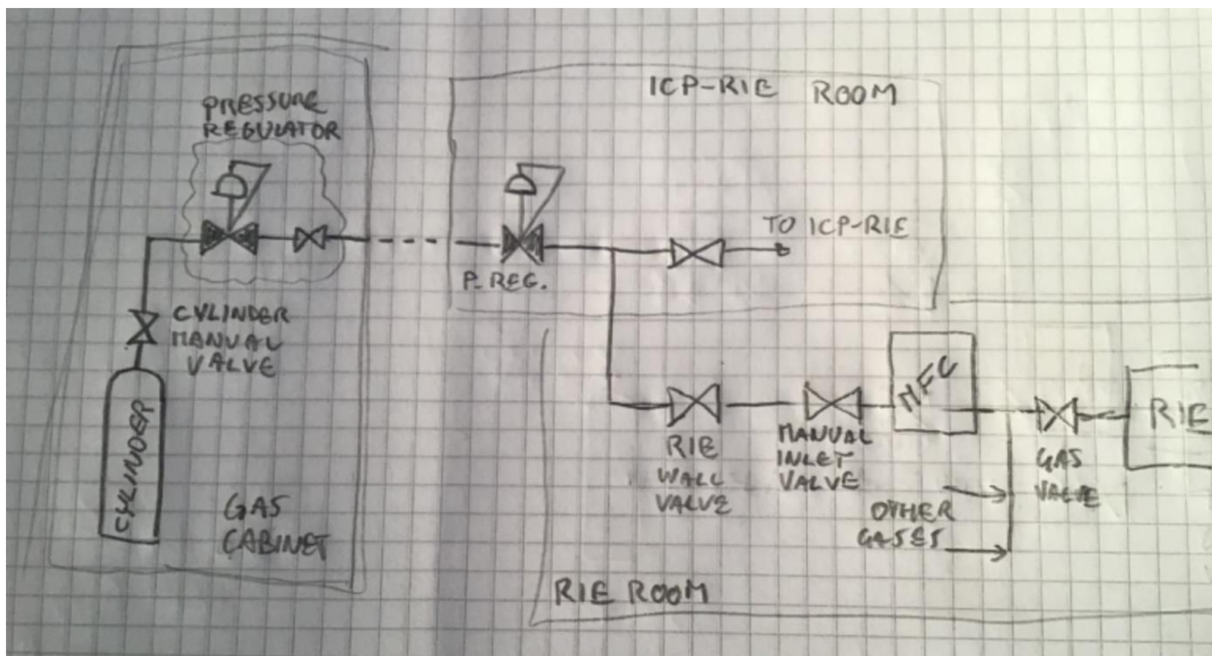
A set point is OK when the corresponding channel P, goes below the “LO” value. When OK it continues to be OK until the corresponding channel pressure is not above the “HI” value. The existence of two values is necessary for several reasons:

1. it avoids that when the pressure crosses the setpoint it switches ON/OFF continuously very fast
2. it allows to start a process only after going below a certain "base" pressure which is the vacuum level before inserting the gases, but will not stop it when "clean" process gases are injected, until a failsafe level for the turbo

Set Point #	CH	LO (mbar)	HI (mbar)	OK	Not OK
1	1	5E-2	8E-1	BP is closed, FL and HV is opened, throttle mode can be selected	Gate/throttle are closed, FL is closed, BP is open
2	2	4.2E-2	3.32E-1	FL can be closed to open BP	BP is closed and FL opened
3	2	5E-2	9.7E-1		
4	1	1	1.1	Not used	Not used

Gas line schematics

Each gas line from a bottle typically has a high-pressure regulator right after the bottle, and a low-pressure regulator in the cleanroom, near the ICP. There the lines split in two branches, serving the RIE and the ICP-RIE. In the RIE room, at the wall behind the equipment there's a manual shutoff valve, and another one (the "manual inlet valve") is when the line reaches the machine, directly attached to the MFC.



Abbreviation key

MFC: Mass Flow Controller, operated through the GFMC

GFMC: Gas Flow Meter Controller, the interface to the MFC2

RF: radio frequency

PCU: Pumping Control Unit, the interface the the vacuum logic, used to control the vacuum valves

DCU: Digital Control Unit, the interface to the Turbo Pump

Version history

Version	Date	Author(s)	Notes
0.1	2024-10-09	D. Ercolani	First draft
1.0	2024-10-15	D. Ercolani	First released version. Detailed gauges setpoints and vacuum logic, detailed the RF generator usage procedure.
1.1	2024-12-06	D. Ercolani	Corrected a few minor typos.