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1. Changes compared to previous versions

Date	Page number	New version number	Description
22-12-2010		/01	English version of Dutch documents RWV-011-040-011/02 (2007) and RWV-010-23-99003-01 (2003)

2. Safety

2.1 General

Emergency off breakers:

On several locations, the tool is equipped with **red yellow** coloured emergency breakers that can be pressed in case of dangerous situations with the tool. The tool is separated from the main electrical supply then (except for the rough vacuum pumps on the first floor), and process gas supply to the tool is blocked. Pressing the **black white** switches 'werkschakelaars' located near the tool has the same effect, but that action also includes power down of the electrical wall sockets near the tool.

Electricity / radiation:

The tool meets international safety regulations, such that dangerous situations can virtually be excluded. However, such situations are present if metal covers have deliberately been removed or cables disconnected: then there is danger for high-power electrical shock (220/380V) or high-power RF radiation (13.56MHz).

Gasses and vacuum:

Some process gasses are toxic, corrosive, or even explosive when present outside the tool, but internal tool safety measures are such that this situation can virtually be excluded. Explosive combinations of process gasses cannot be used. What's more, a gas detection system monitors the area around the tool and blocks process gas supply if the slightest concentration of dangerous gas is detected.

Maintenance (by qualified personel only!):

Scheduled preventive maintenance includes cleaning of the process chambers. Chambers are opened for cleaning then, but not before the chambers have been subjected to a 30 minutes oxygen plasma clean and the installation of an exhaust hood to remove dirty gasses. It is advised to wear a gas mask with appropriate filters for harmful gasses and small particles.

2.2 Chemicals

Dangerous process gasses used inside the tool are: Chlorine (Cl_2), boron-trichloride (BCl_3), hydrogen-bromine (HBr), methane (CH_4), hydrogen (H_2) and oxygen (O_2).

Far less dangerous gasses include sulfur-hexafluoride (SF_6), tetrafluormethane (freon-14, CF_4), and trifluormethane (freon-23, CHF_3). However, when inside the process chambers and decomposed in a plasma, these gasses generate dangerous components.

Detailed information about these chemicals can be found in the corresponding Material Safety Data Sheets (MSDS).

3. General information

The <STS RIE Cluster> tool is a vacuum system for 'dry' Reactive Ion Etching (RIE) of materials in a constant flow of plasma-activated process gasses at low pressure (typically 10-100mTorr). One chamber (RIE-1) mainly applies chlorine-, oxygen-, or hydrogen-based chemistry, whereas a second chamber (RIE-2) mainly applies fluorine-based chemistry:

Process chamber RIE-1	Process chamber RIE-2
Cl ₂	SF ₆
BCl ₃	CF ₄
HBr	CHF ₃
CH ₄	-
H ₂	-
O ₂	O ₂
N ₂	N ₂
Ar	Ar

Recipes are available for etching:

Si, Al, Cr, Mo, Ta, Ti, TiN, W, ITO, polymers, resist, etc. in RIE1
Si, SiO₂, Si₃N₄, Mo, Ta, W, polymers, resist, etc. in RIE2

Consult the machine owner about the most suitable recipe for your application.

Reaction products are removed from the system by vacuum pumps. The RIE technique is mainly limited to the etching of those materials that produce volatile reaction products.

Substrate transfer to and from the process chambers is carried out by a vacuum robot, there is virtually no risk at all for exposure to dangerous chemicals or gasses.

4. User Manual – Part 1: manual control mode

4.1 Mimic and control windows

The *Cluster Operator Station* is displayed on the monitor as a composition of sub-windows. There are two kinds of windows:

- *Mimic* windows, containing information only, and
- *Control* windows, allowing user interaction with the tool by means of command buttons.

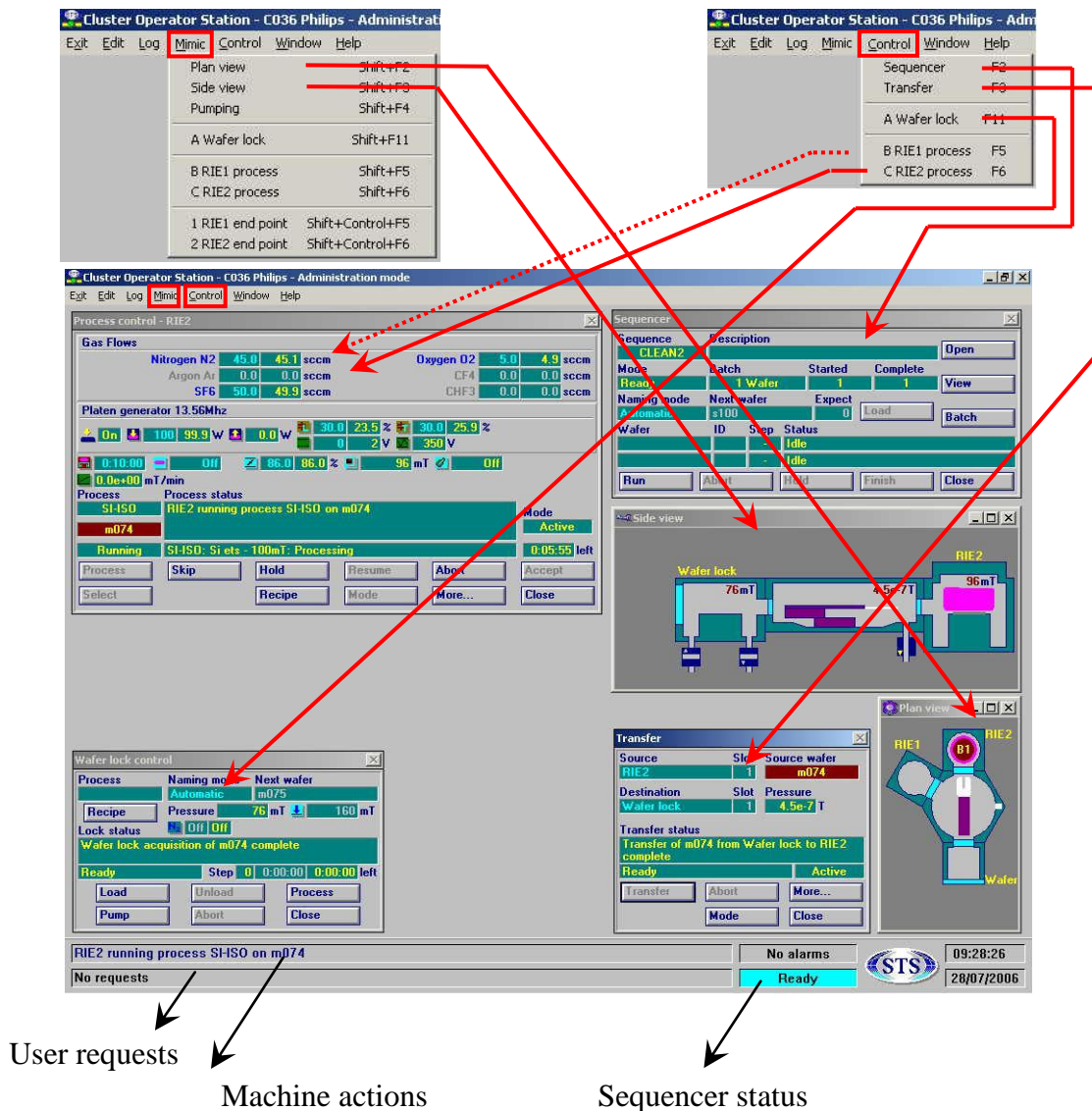


Fig. 1: Full screen with Mimic and Control windows.

If the *Cluster Operator Station* is not visible on the desktop, move down to the pop-up task bar (Fig.2) and click on *Cluster Operator Station* or its icon (left).

On the task bar: **NEVER close Data Exchange !!**

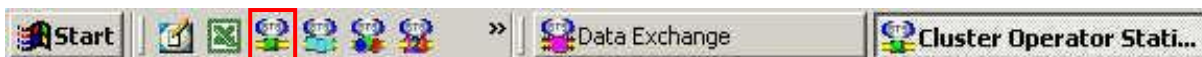


Fig.2: Task bar

With the *Mimic* windows *Plan view* and *Side view* the user can trace down the position of wafers, follow the actions of the robot that transfers wafers between load lock and process chambers. The user may also check pressure readings.

The *Control* window *Wafer lock control* allows manual control over the load lock and the window *Transfer* over the transfer robot. The *Sequencer* is for automated operation.

Process control is enabled by the *Control* windows *Process control - RIE1* and *Process control - RIE2*, for the process chambers called RIE1 (primarily chlorine based gasses) and RIE2 (primarily fluorine based gasses), respectively.

Finally, running processes may be viewed by the *Mimic* windows *RIE1 process view* and *RIE2 process view*, although this option has little extra value: all information is already displayed in the *Process control* windows, albeit in a less graphical way. Usually these mimic windows are switched off.

4.2 Wafer unloading/loading and transfer

The etch tool is 'blind', there is no substrate sensing present. The system relies on the actions of the user and takes for granted that a substrate has physically been loaded into the load lock after the *Load* command, even if that action has been omitted!

Take notice of the wafer constraints (Sect. 7.1 of this manual) !

The user is responsible for damage-free handling of substrates.

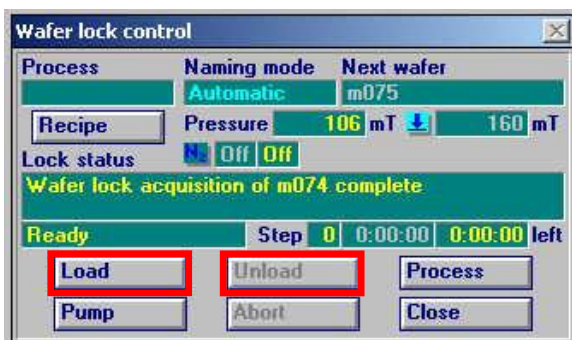


Fig.3: Wafer lock control window

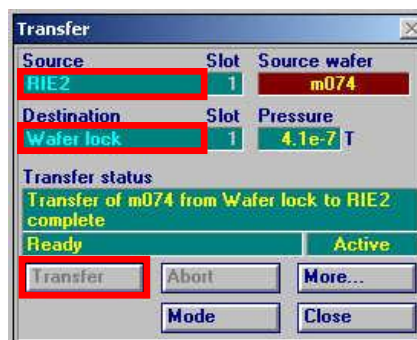


Fig.4: Transfer control window

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Common practice in *stand-by status* is to leave the Load lock under vacuum, with the (empty) carrier plate inside. Consider the empty carrier plate as a (dummy) substrate.

4.2.1 In the **Wafer lock control** window (*Fig.3*), press the **Unload** command to vent the Load lock. Wait for the load lock to come at atmospheric pressure, observe the decreasing pressure on the O-ring seal through the transparent load lock lid.

4.2.2 Gently open the lid (it has a stable - almost upright - 'open' position). The substrate mimic on screen will disappear (even with the carrier plate still in place!).

4.2.3 Place your substrate on the carrier plate (mind the constraints *About wafers...*), don't close the lid at this moment !!

If the etch monitor (Sect. 6) is to be used: be sure that the location of interest on the wafer is close to the centre of the carrier plate and in this way accessible for the laser beam.

4.2.4 Press the **Load** command and - after that - close the lid (substrate mimic will appear on screen). Pressure will go down and - in the end - will automatically be fixed in a window between 80 and 160mTorr.

4.2.5 In the **Transfer** window inspect the *Source* and *Destination* lines. The source line should read *Wafer lock*, the destination line *RIE1* or *RIE2*, whatever you intend to do. Adjust the lines if necessary with a mouse click on the lines.

By the way, *Arm* is the position on the robot in the transfer chamber, a popular position for first wafer inspection through the glass window after etching.

4.2.6 If the start and end location are alright, press the **Transfer** button. The substrate will go from the wafer lock to its destination.

After processing it takes similar actions to get the substrate back into the load lock. For the next substrate the procedure starts from step 4.2.1 again.

Common practice in *stand-by status* is to leave the Load lock under vacuum, with the (empty) carrier plate inside. Before closing the lid, the last command thus will be **Load**.

Automated wafer naming is active: when manually loaded via the *Wafer lock control* window, wafers and etch runs will get an **m**-number (e.g. m074). This unique wafer number can be useful, if - later on - you are interested in the process details: all run data are automatically stored into a data base.

Please don't forget to fill in the log book, including the substrate / run numbers.

4.3 Select recipe and check/change process time

4.3.1 Press the **Select** button in the **Process Control** window of RIE1 or RIE2 (*Fig.5*). If you accidentally press *Process*, a process will start, immediately press *Abort* in the process control window then and the process will stop.

4.3.2 Select the right recipe from the pop-up menu, confirm with **Select**, the system will prepare the chamber for processing (purge and pump). The chamber mimic will be coloured in blue during this preparation.

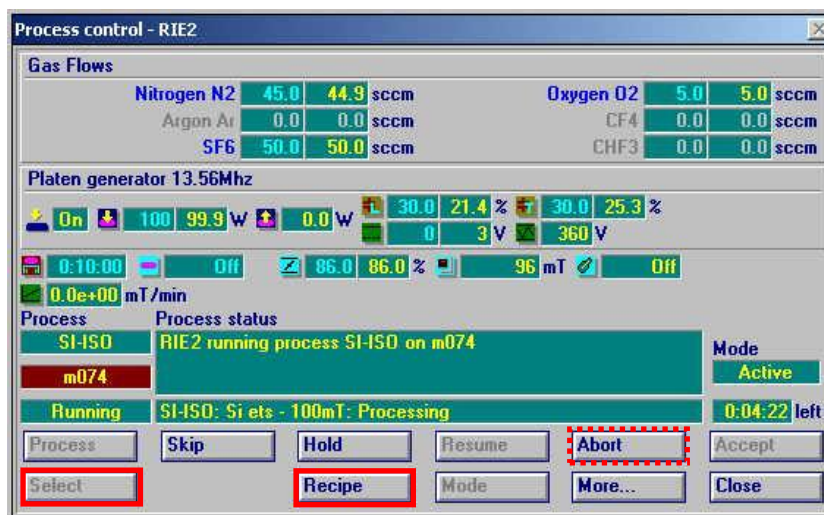


Fig.5: Process Control window (RIE-2).

4.3.3 Press **Recipe** to enter the *Recipe Editor* (Fig.6) to check or change the process time.

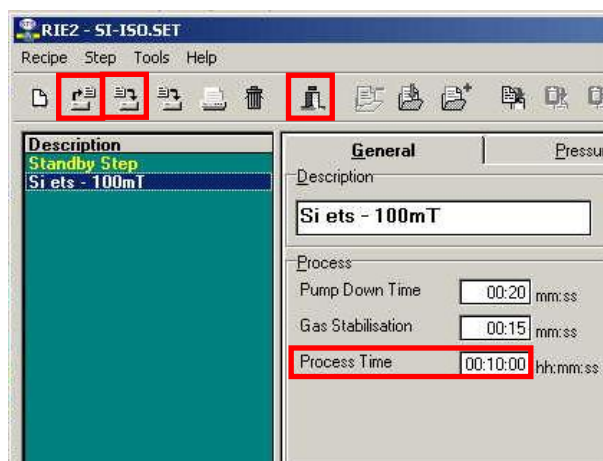


Fig.6: Recipe Editor (RIE-2).

4.3.4 In the recipe, ignore *Gas line Purge* and/or *Standby Step*. Select the **process step** and the tab **General**, ignore all other tabs.

The user is limited to change the **process time** only, and even then with an exception: **never change the etch times in multiple-step recipes designed for interrupted etching**. They contain sets of alternating etching and cooling steps and the wafer heat balance changes if the process times are changed.

If endpoint detection is used: choose a process time in the recipe that is for sure much longer than the estimated etch time.

4.3.5 Save the recipe before closing the editor, either by **Recipe/save** and **Recipe/close** or by the using the corresponding icons.

Always consult the machine owner if you like to make parameter changes in available recipes or if you like to make a new recipe.

Like you, all other users rely on fixed and unchanged recipes !!

4.4 Run an etch process

After loading a wafer (Sect.4.2), and selection of the right recipe and adjustment of the process time (Sect. 4.3), an etch run can be carried out from the *Process Control* window.

4.4.1 Start the selected process by pressing **Process**.

Each process run starts with a *Standby step* in which the process chamber is prepared for processing (chamber purge and pumpdown). An extra pump purge delay (30s) may start if the chamber has not been in use recently.

After process gas stabilization (typically 15s) a plasma will be ignited, the colour of the chamber mimic will change to purple.

The *Process Control* window (Fig.7) shows all details about the process parameters, **blue** = set value, **yellow** = actual value.

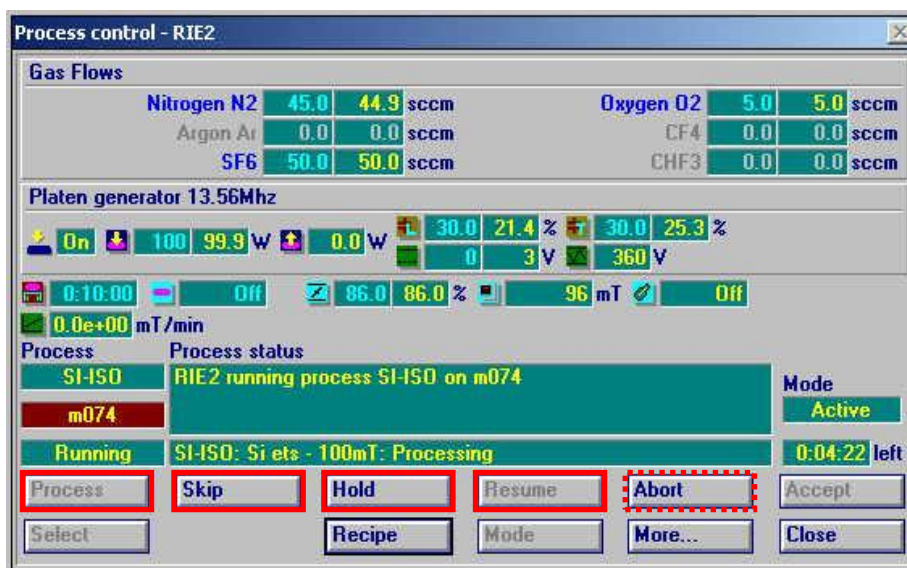


Fig.7: Process Control window (RIE-2)

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4.4.2 If really necessary, the process may be interrupted by pressing **Hold** (plasma *off*) and later on continued by pressing **Resume** (plasma *on* again), but that procedure is exceptional and it is not recommendable to do so.

Hold can be pressed whenever the timer in the right-hand corner is counting down, for example during the purge or pumpdown of standby steps, gas stabilization (before plasma ignition), or during processing.

Skip. A single process step can be ended by pressing **Skip**. That specific process step will be stopped and the recipe will continue with the next process step or return to *Standby step* (if there is no next step in the recipe). This is the most common way to stop processing, for example when the etch monitor system shows the user that an 'endpoint' and some overetch time have passed.

Skip can be pressed whenever the timer in the right-hand corner is counting down, for example during gas stabilization (before plasma ignition), or during processing. Please don't skip the standby steps (before and after processing), these steps are there for good reasons and should not be omitted.

In a multiple-step recipe the etch run may be terminated by **Abort**, all steps will then be skipped at once.

[Note that such an abort action is not appreciated by the sequencer, if the etch run is part of an automated sequence run: the sequencer will go in hold and wait for a user command.]

4.4.3 The process will automatically end with the *Standby step*, preparing the process chamber (purge, pumpdown) for wafer transfer and a next wafer run.

5. User Manual – Part 2: automated control mode

The *Sequencer* is for **automated** process runs. The *sequencer* takes over from the user almost all of the manual actions described in the previous sections!

The user puts all information required by the etch tool into a procedure called *Sequence*, saves the sequence under some name (for later use) and sets the process times in the recipes that are involved in the that specific sequence.

The sequence will take care of wafer transfer and selection plus run of the programmed etch recipe(s).

5.1 Set up a sequence

A sequence is nothing more than a list of lines, each line representing the etch chamber (RIE1 or RIE2) and the etch recipe to be used for wafer processing.

5.1.1 To open the *Cluster Sequence Editor* window press **Edit / Sequence editor** in the main menu bar, a blank sequence called 'not named' is shown then.

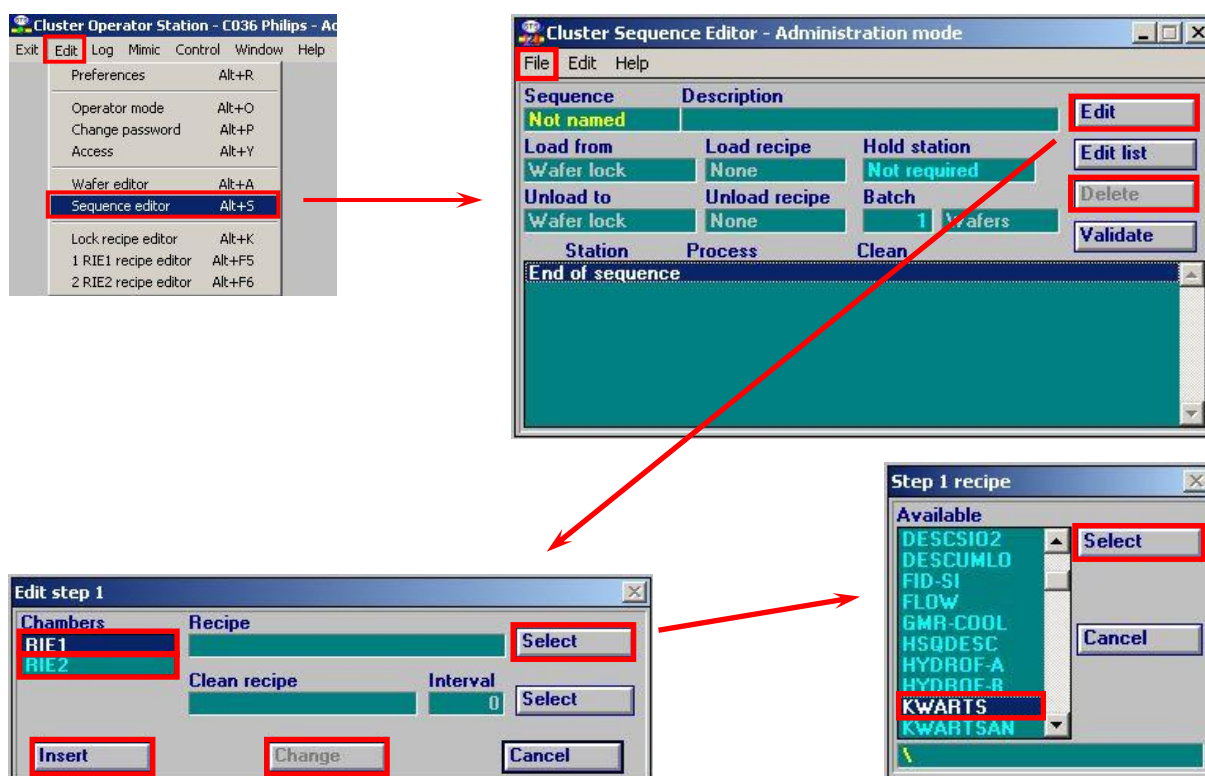


Fig.8: Sequence Editor window

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5.1.2 Press the **Edit** button to edit the first sequence line. A new selection window called **Edit step 1** will show up.

5.1.3a In the left-hand corner select the process chamber by clicking on **RIE1** or **RIE2**.

5.1.3b In the right-hand corner press **Select**, a **Step 1 recipe** window will appear with a listing of all recipes available in the selected chamber.

5.1.4 Select your **recipe** with a mouse click on the recipe (for example *kwarts*) and then press the **Select** button.

The **Step 1 recipe** window disappears and the name of the selected recipe shows up in the **Edit step 1** window.

5.1.5 Now the option **Insert** transfers the information from the **Edit step 1** to the **Cluster Sequence Editor** window.

In principle the sequence list can be as long as you like. A new line can be added right above an existing one by clicking that particular line and following the steps 5.2 to 5.4 again.

An existing line can be removed directly with **Delete**, or replaced by a new one with **Change** after editing.

5.1.6 Save the new sequence via **File / Save as**, the system will ask you for a name (8 characters maximum).

5.1.7 Exit the sequence editor via **File / Exit** (confirm *Exit*).

5.2 Run a sequence

5.2.1 In the *Sequencer* control window press the **Open** button, and **select your sequence** from the pop-up list. This sequence will then appear in the text box in the upper left-hand corner of the sequencer control window.

If you don't have a sequence set up yet, go to Section 4.6 to make a new sequence.

5.2.2 If you like to check the sequence: open the sequence editor by pressing **View**. Alternatively, you may press **Edit / Sequence editor** on the main menu bar, press **File / Open** and select the right sequence.

5.2.3 Set the right **process time(s) in the recipe(s)** invoked by the selected sequence. The simplest way is to open the recipe editor by pressing **Edit / Recipe editor** in the main menu bar, open the recipe(s), set and save the recipe(s) following the steps 4.3.3 – 4.3.5 described earlier.

5.2.4 Put a wafer on the carrier plate in the load lock, don't close the lid at this moment !! If the etch monitor (Sect. 6) is to be used: be sure that the location of interest on the wafer is close to the centre of the carrier plate and in this way accessible for the laser beam.

5.2.5 Press the **Run** button in the sequencer to **run the selected sequence**. It is this command that takes in the place of the *Load* command when loading the tool via the *Wafer lock control* window.

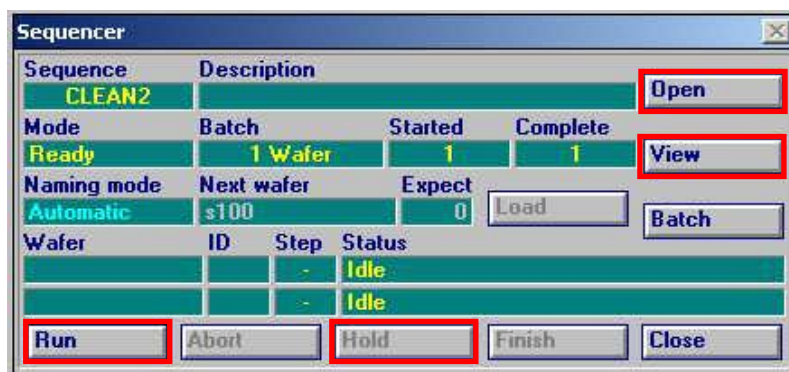


Fig 9: Sequencer window

One by one the sequencer will guide wafers through the etch tool and bring them back to the load lock after processing.

It is an automated command-by-command 'sequence'. **Manual intervention is still possible at every moment!!!** The button **Hold** in the *Sequencer control* window will interrupt a sequence in the sense that a running action (transfer or process) will be finished before the actual interruption is to take place. The user is then asked what to do afterwards: **Stop** (take over command by manual control) or **Continue** (sequence proceeds). Likewise, all control buttons in the *Process control* window are available for use (just in case...).

When the *Sequencer* is used, **automated wafer naming** produces s-numbers. This unique wafer number can be useful, if - later on - you are interested in the process details: all run data are automatically stored into a data base.

5.2.6 At the very end, leave the load lock under vacuum after pressing **Load** in *Wafer lock control* window.

5.2.7 **Please don't forget to fill in the log book, including the substrate / run numbers.**

6. User Manual – Part 3: endpoint detection (etch monitor)

Both chambers of the STS etch tool are equipped with an optical endpoint detector. A laser beam is pointed at a selected spot on the wafer (camera observation) and the intensity of the reflected beam is monitored (more details can be found in Sect.6.9).

The laser spot size dictates a clear 'open' area of at least 100-150µm diameter.

There is **NO interaction between the etch tool and the detector**, there is no automated communication about 'start process' or 'stop process' between them.

The detector itself is operated in a **passive mode**: the judgement about endpoint and overetch time is up to the user while viewing on screen the evolution of beam intensity.

If the **Laser End Point** window is not present on the left-hand monitor: start with step 6.1, otherwise skip that step and go to step 6.2.

6.1 Intellimetrics' EPD program runs on a computer on top of a big electronic power rack. The PC's password in administration mode is **adm**.

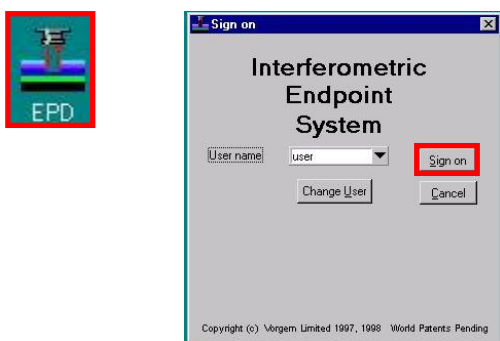


Fig.10: Sign-on window

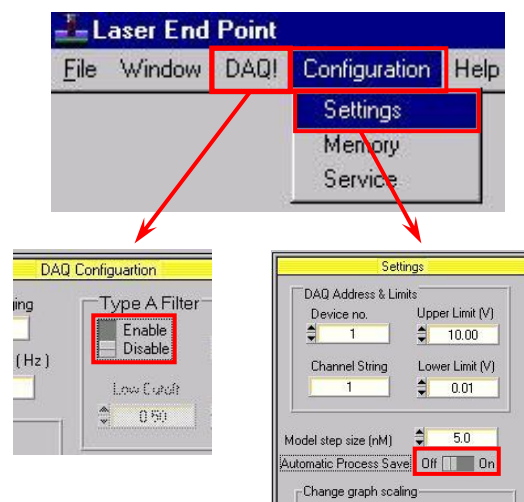


Fig.11: Default settings.

On desktop, start the EPD program using the **EPD** icon, a **Sign on** window will appear (Fig.10). Press **Sign On**, the EPD control window **Laser End Point** will appear. Maximize that window.

In the **Laser End Point** window, **change two default settings** (Fig.11):

Press **DAQ!**, a **DAQ configuration** window will appear. Switch the **Type A filter** from Enabled to **Disabled**, confirm with **OK**.

Press **Configuration / Settings**. In the **Settings** window switch **Automatic Process Save** from On to **Off** and press **Hide**.

6.2 **Select the right camera** (each process chamber has its own EPD camera).

Make the same selection on TWO boxes below the monitors:

the **Video Switcher** (top) and the **Camera Input** (bottom):

1 = EPD camera on chamber RIE-1,

2 = EPD camera on chamber RIE-2,

3 = not in use (spare)

6.3 On the **Intelmetric** PC (on top of power rack) open the small door with the key and:

a. Switch on the **field illumination** (green switch)

b. Switch on the **laser beam** (red switch)

Please do not touch the gain and offset knobs!

When a substrate is in the process chamber its **image** can now be seen **on the screen on the wall**. The field of view on the monitor measures **2.2x1.6mm**.

If necessary adjust **focus** and **intensity** (big and small adjustment ring on the camera).

6.4 **Move the laser spot to the location of interest** using the (X,Y) micrometer screws.

The entire camera system can be moved around by 7 to 8mm in all directions around the center position, at the edges at the expense of light intensity and spot quality. The micrometer reading (10,10) is close to the camera's central position.

It is important that the laser spot has sufficient access to the film-to-be-etched and has no overlap with the mask material (for example resist):

The laser spot size dictates a clear 'open' area of at least 100-150µm diameter.

6.5 Adjust the **laser beam intensity** using the small diafragm ring on the camera.

The intensity is displayed on the control screen and indicated as **Signal (v)**.



Its value is limited to the range 0 - 5.0V, and it is wise to adjust the camera diafragm (small adjustment ring) such that the start value is somewhere between 1.0-3.0V, if possible.

6.6 Open a **Process** window via **File / New / Process** (Fig.12).

In this mode of operation only three 'knobs' are active:

- **Process** to start data collection.
Press this button shortly before plasma ignition during gas flow count-down (stabilization) on the STS tool,
- **Signal** to (re-)activate automatic plot scaling during data collection.
- **Stop** to stop data collection.
Press this button after the etch process has been stopped by the command *Skip* on the STS tool,

For each process run you have to open a new process window via **File/New/Process.**



Fig.12: Process window

6.7 Closing down

Switch off the **field illumination** (*green* switch)

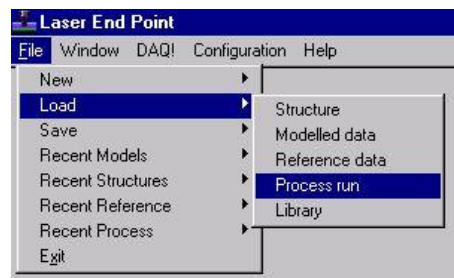
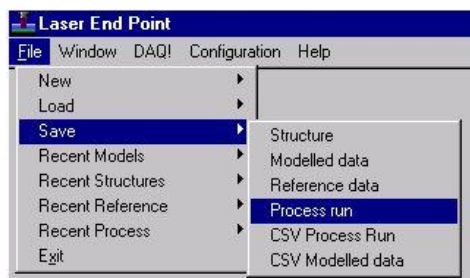
Switch off the **laser beam** (*red* switch), the laser diode has limited lifetime.

Switch off the **LCD monitor**.

6.8 Options

6.8a Save data

A process run can be saved via **File / Save / ProcessRun**, under a name and folder to be chosen by the user. The **file extension** automatically is **.dat** then, a format readable by the EPD program only.



Such files can be reopened at any time via **File / Load / Process run** and displayed on the monitor.

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6.8b Data transfer and printing

Data can be exported or printed in an indirect way only, as the system (intentionally) is not connected to a network. For obvious reasons the data format has to be different from *.dat*.

A fresh run (or a reopened old one) can be saved (again) via **File / Save / CSV Process run** on a 'clean' (virus-free) 1.4MB floppy disk that has to be inserted into the Intellemetrics PC.

CSV files (Comma Separated Values) can easily be read and edited by Microsoft Excel (on another PC). In this way graphs can also be printed or imported into reports.

6.8c Simulation of the etch process

Within certain limits, the etch process for a stack of thin films can be simulated by the EPD software. For all materials – including the substrate material – the **n** and **k** of the complex index of refraction have to be known at the laser wavelength (670nm), as well as all thicknesses of the films in the stack. Then, a software programme calculates the intensity of the reflected laser beam as the stack is etched down. The result is a plot of **intensity** versus **etch depth** (not versus time!). Consult the machine owner if you like to go into more detail.

6.9 Principle of operation

The laser EndPoint Detector (EPD) system is based on measurement of the intensity of light reflected by the substrate. A laser beam is focussed to a spot on the substrate and reflected back to a photosensitive detector. Both the spot (red, 670nm) and its surroundings (green field illumination) are observed by a camera (the view on a monitor is black&white only).

Etching an opaque film (for example a thick metal film) will result in a more or less constant reflected signal until the film becomes very thin. Then the reflected intensity will drop (or rise, depending on the reflectivity of the underlying material) until the film interface is reached.

Etching a more or less transparent film (for example a poly-silicon, silicon oxide or -nitride layer) will result in a reflected intensity that oscillates with time. Because the original beam reflects back and forth between the top and bottom interface of the transparent film, interference between the multiple reflected beams causes the oscillations. Constructive interference results in maximum intensity, destructive interference in minimum intensity.

7. Rules & Regulations

Please take notice of the following remarks about (7.1) substrates, handling, (7.2) cleaning and conditioning, and (7.3) excluded processes.

7.1 Substrates and handling

7.1.1 Substrates (wafers, rectangular plates, pieces) of any size can be handled, as long as the substrates fits *within* the outline of the 200mm fused-quartz carrier plate. Wafer flat orientation is not an issue, any orientation will do.

Substrates always have to be supported by the carrier plate, the only exception being full-sized 200mm wafers.

Never start a process without a carrier plate in the etch chamber, it will attack and damage the platen.

Substrate **height** and **weight** are limited. Heavy substrates should always be loaded with their center of gravity close to the hart of the carrier plate (prevent tumbling of the carrier plate: the central lift mechanisms have small base dimensions!).

The user is responsible for damage-free handling of substrates. In case of doubt: consult the machine owner.

7.1.2 Relatively large substrates tend to drift away from their original positions during pumpdown of the loadlock (air cushion effect). This can be prevented by putting small pieces of silicon (few millimeters in size) around such substrates, in contact with their edges.

7.1.3 Optical endpoint detection is successful only when the location of interest on the wafer is positioned at or nearby the hart of the carrier plate. If possible substates have to be placed on the carrier plate accordingly.

7.2 Cleaning and conditioning

Because many different materials are etched in the same chamber with different recipes, best and most reproducible results are obtained only after proper cleaning and conditioning of that etch chamber (using an empty carrier plate):

First give the chamber a **plasma clean**, using the recipe(s) <clean-1> 1min step1 + 10min step2 in RIE-1 or/and <clean-2> at least 10m in RIE-2.

Again using the empty carrier plate, proceed with a **conditioning** run for a certain period of time using the recipe you are going to use for etching your substrate.

Note that in general the amount of material exposed to the plasma influences etch rates. Etch rates tend to go down as 'open' surface area increases. Therefore, it is recommended to do a calibration run in advance with a dummy wafer identical to the 'real' wafers.

Consult the machine owner about the most suitable recipe for your application and the details.

7.3 Excluded processes

Pure sputter etching (e.g. in an argon plasma) is not allowed in the etch tool, as it leads to chamber contamination with all negative consequences for you and all other users of the system. Ion Beam Etching (Veeco system E17) is an excellent alternative way of processing.

As soon as the to-be-etched material has opened, the underlying material is exposed to the plasma during the usual overetch period. That material may be gold, platinum, copper or alike, materials that are not supposed to be exposed to plasmas, especially in case of high-bias recipes: no matter what chemistry is used, a sputter component will always be present and responsible for material removal. This will contaminate the etch chamber. In all cases, contact the machine owner about options.

8. Instruction and test

An introduction to the tool is given by the machine owner. Normally the instruction will take about one hour. First the major parts and possibilities of the machine will be explained. After this the operating instructions will be explained following the User Manual as described in Chapt. 4-6.

Subsequently the potential user will operate the system, independently as a test. If successful, the user is authorized to use the tool and his/her name will be added to the users list in the equipment reservation tool.

If it turns out that some users operate the etch tool with very large time intervals, it becomes questionable whether those users still know how to operate the system properly. In that case, the tool owner may consider to contact those persons and withdraw their authorizations.