IMP End Point Detector
User Manual

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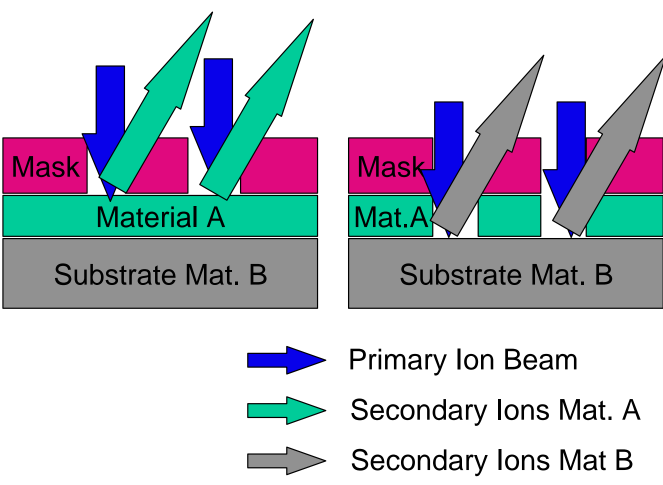
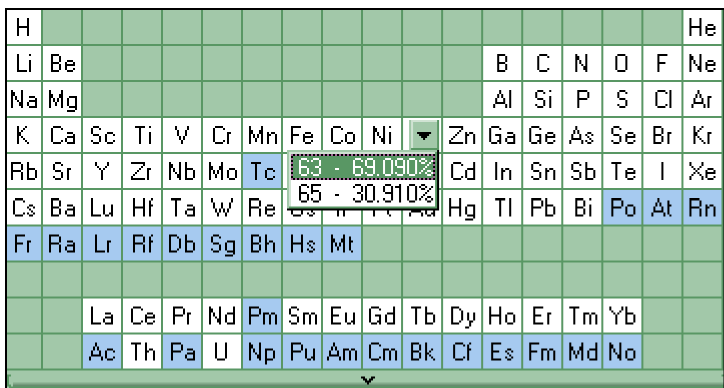
1. The Quadrupole Mass Spectrometer

The Hiden IMP-EPD (Ion Milling Probe – End Point Detector) is based on a Quadrupole Mass Spectrometer. When a wafer is etched “secondary” ions are emitted, these are ions of the material etched from the wafer – so when you etch through a Tantalum layer you get Tantalum ions.



Every ion has a mass according to its position in the periodic table. The mass of ions are measured in Atomic Mass Units (amu). Ions of molecules (like Al_20_3) have a mass that depends on their molecular weight.

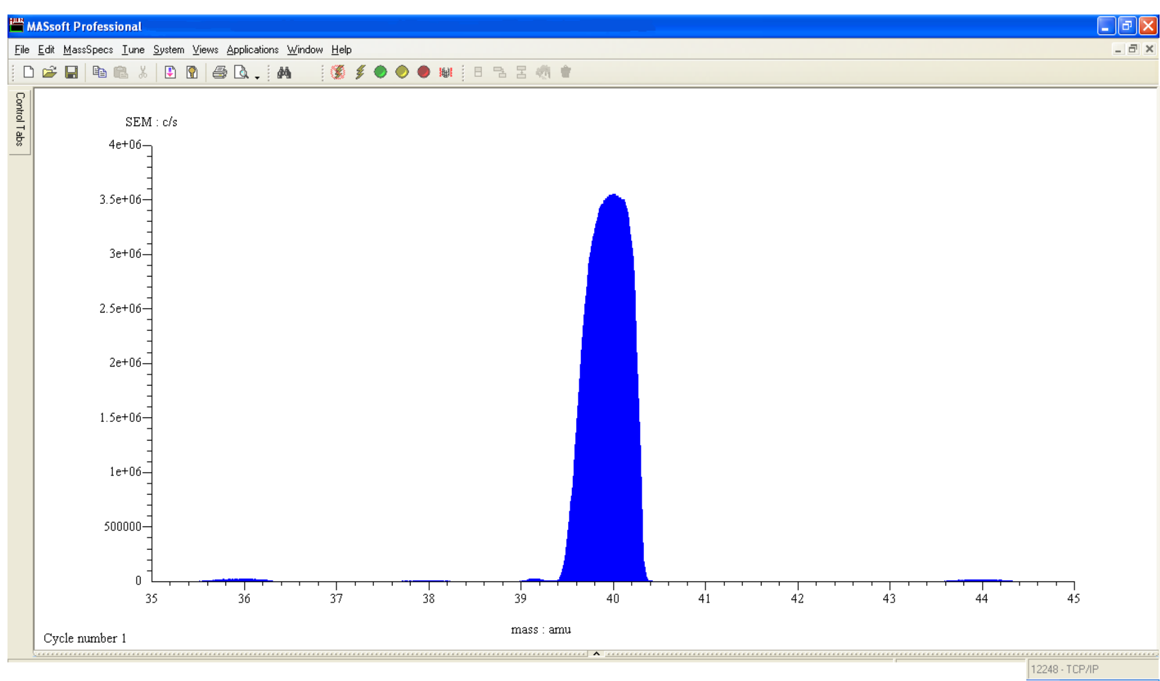


A Quadrupole Mass Spectrometer consists of four precisely aligned metal rods to which are applied DC and RF voltages; this combination acts like a filter that allows only ions of a single mass through

By altering the voltages on the rods the Mass Spectrometer selects the mass that can get through the filter, like tuning a radio to a particular station. The analyser (which contains the Quadrupole Mass filter) and the RF head (which supplies the RF and DC voltages) are supplied as a matched pair. If the head is not matched to the rods then the Mass Spectrometer will, literally, not tune in properly; The RF head and Analyser must always be kept together as a matched pair.

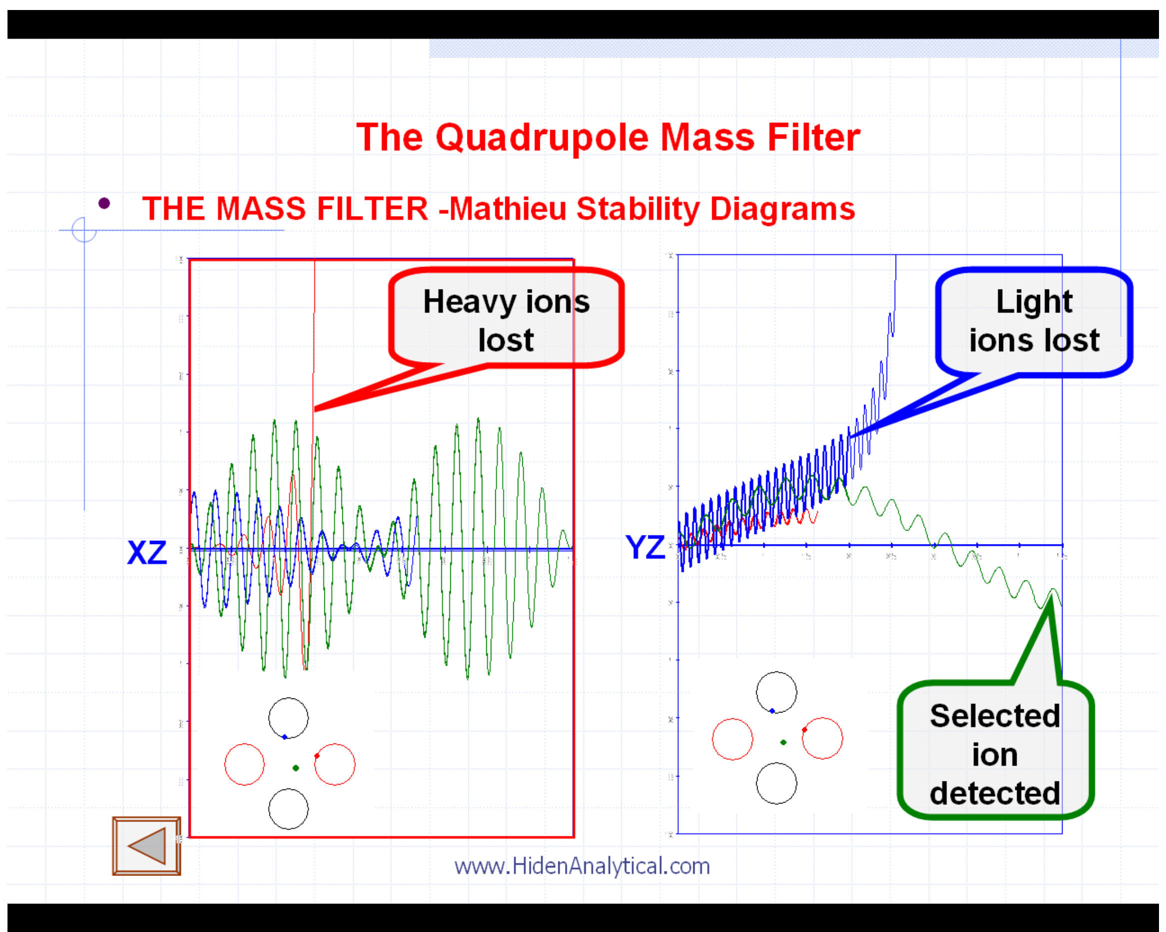
Each ion has a precise mass, for instance Cobalt (Co) is exactly 58.9332. For convenience we always round this up to the nearest whole number e.g. 59. This is unlike optical endpoint detectors where the emissions of an ion will cover a wide range of wavelengths which may overlap with other ions. Because each mass is characteristic of a single ion it is rarely necessary to measure more than one mass to measure a particular element.

When you tune a radio to a station the signal gets louder the closer you are to the stations frequency and then, if you tune too far, starts to get quieter again. The same is true of the Quadrupole Mass Filter. If we scan from the mass below an ion to the mass above the ion the signal rises and falls in the same way; in the MASsoft software this can be done in a “Profile” scan.



Profile scan of a peak

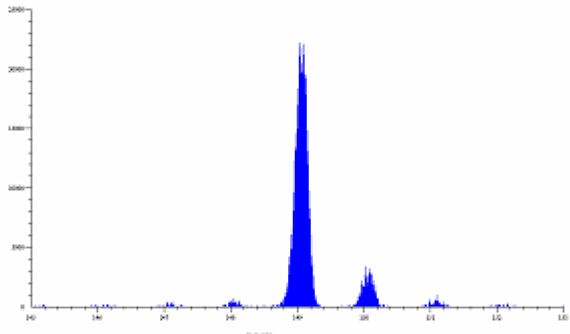
Above is a scan of Argon. Argon has a mass of 39.9624 so the peak has a maximum at mass 40. When the filter is set to 38.75 the ion being measured still has a mass of exactly 39.9624 – the mass is precise, it is the cut-off of the filter that has some lee-way. This is inherent in the design of a quadrupole filter, which behaves like a combination of a high pass and low pass filter;



Matheiu stability diagram

In fact we can alter the width of the filter and adjust the “resolution”. If the resolution is increased the peaks become narrower; increasing the resolution has the side effect of decreasing the signal. Conversely we can reduce the resolution and make the peaks broader and bigger.

Why might you want to increase the resolution? Consider the radio analogy again, if you are trying to listen to a quiet station that is adjacent to a station with a very strong signal you might find that the strong signal breaks through and can be heard in the background all the time. The same can occur if there is a big peak adjacent to the ion you are trying to measure; you may find that the shoulder of the adjacent peak interferes. By increasing the resolution you can make the filter more selective and decrease the adjacent signal.



The disadvantage of increasing the resolution is that as the peaks become narrower and sharper the more precisely you have to select the top of the peak to get the maximum signal – if you measure at integer masses the top of the peaks must be more precisely "aligned" with the corresponding axes tick marks.

The procedure of making sure that the top of peaks correspond to the correct integer mass number is known as "aligning the mass scale".

If the mass scale is not correctly aligned peaks will not be read at their apex.; this has two consequences:

1. A loss of sensitivity because you are not reading the maximum signal.
2. A less stable signal. On the flat(ish) top of the peak a small inaccuracy of position will cause a small change in signal. On the steep side of the peak a small change in position will cause a large change in signal.

Small changes in position can be caused by thermal drift in the RF head; provided that the resolution is not set to high this will not have a significant affect on the signal intensity. Actually it is change in *apparent* position, it is the RF generator that drifts, the mass of the ion is always exactly the same e.g. 62.9296 for Cu.

The mass alignment of the IMP EPD should be checked regularly as part of the Preventative Maintenance schedule.

Note: In quantitative measurements the *area* of a Profile scan peak (intensity v mass) tells you nothing significant; when measuring a peak you want to read its *maximum* value. A profile scan gives you qualitative information about the performance of the Quadrupole filter.

1.1. Isotopes, and other factors affecting sensitivity.

The fact that increasing the resolution decreases the sensitivity has already been noted. There are other factors that affect sensitivity, the most important of which is isotopic abundance.

The nucleus of an element consists of protons and neutrons, together the number of these determine the atomic mass of an atom. For a given element the number of protons is fixed, but the number of neutrons can vary, giving rise to *isotopes.* How does this affect sensitivity? Lets consider Gold (Au) and Platinum (Pt) as examples.

Gold only has one stable isotope Au^{197} with an atomic mass of 196.9672 amu.

Every time you etch a gold atom from a wafer it has a 100% probability of having a mass of 197 amu. If you set the quadrupole mass filter to 197 it will allow all the gold ions to pass.

However platinum has 6 stable isotopes:

0.012%	Pt^{190}
0.78%	Pt^{192}
32.8%	Pt^{194}
33.7%	Pt^{195}
25.4%	Pt^{196}
7.23%	Pt^{198}

If you measure Pt at mass 195 only 33.7% of the ions etched will have this mass, the remaining 66.3% will be blocked by quadrupole filter, so the peak will be 1/3 of the size it would have been if Pt had only one isotope.

On isotopic abundance alone you would expect the Au peak from an etch to be 3x bigger than a Pt peak, in fact it will be smaller because gold has the lowest Secondary Ion Yield of any stable element.

Caution! Do not confuse isotopic masses and the Atomic Weight of an element. Periodic Tables designed for use in Chemistry show the Atomic Weight of elements – for instance the Atomic Weight of Cu is 63.546. This is based on the natural isotopic abundances of Cu^{63} (69.09%) and Cu^{65} (30.91%) which averages to 63.546. But if you were to measure at 63.546 you would get no or very little signal, there is no peak at 63.546, there are two peaks, at 63 and 65. At 63.546 you would probably miss the 63 peak completely.

Isotope also give rise to the possibility of interference. For instance Ni^{58} has an abundance of 67.76% has the same atomic mass as a minor Iron isotope, Fe^{58}, which has an abundance of 0.33%. However interference like this can usually be avoided by choosing another isotope e.g Ni^{60} which has an abundance of 26.16%.

Interferences like this are limited to elements which are adjacent in the periodic table, they are rare and usually insignificant.

One interference of note is that of Au^{197} with Tantalum Oxide, TaO, (181 + 16)

Sensitivity to ions tends to decrease as the mass increases because the Quadrupole mass filter is less efficient at passing and detecting heavier ions.

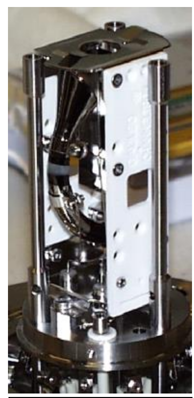
Another factor affecting sensitivity is the “SIMS yield”. (SIMS = Secondary Ion Mass Spectrometery) . The SIMS yield is the measure of the proportion of atoms etched from the wafer that become ionised , in SIMS mode the mass spectrometer can only measure electrically charged ions, not uncharged, neutral, atoms.

The SIMS yield is a property of the electron “shell” surrounding the atomic nucleus which you can not do much about, but it is also affected by the presence of oxygen. Oxygen in the Primary Ion beam, or from oxygen containing layers such as Al_20_3 , greatly increases the SIMS yield.

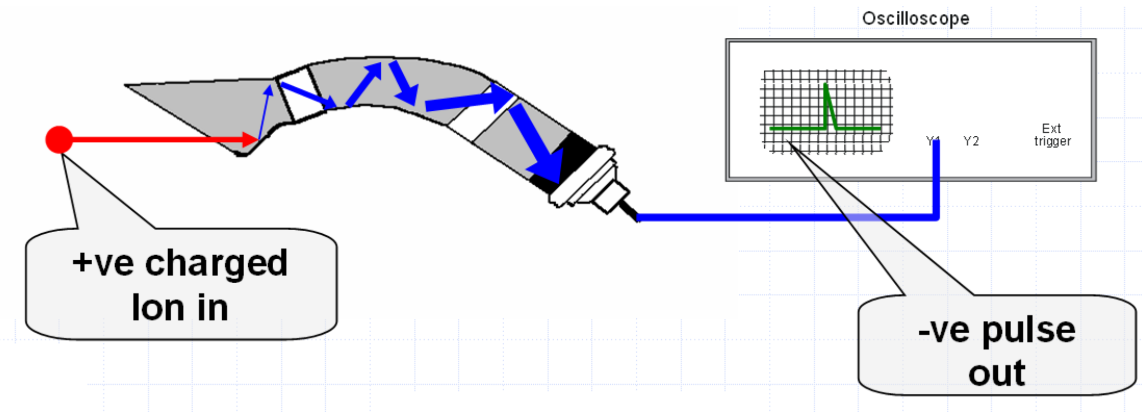
The SIMS yield is also sensitive to electrons in the etch beam so is affected by the Plasma Beam Neutraliser (PBN).

The combination of these two affects means that when you etch down to an insulating Al_20_3 substrate you get a very large signal. If care is not taken this can damage the detector.

1.2. The SEM Detector



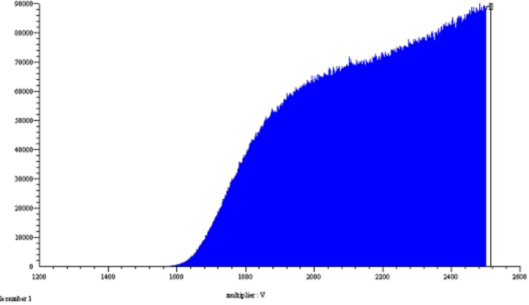
Once ions have passed through the Quadrupole Mass filter they have to be detected. This is done by the SEM (Secondary Electron Multiplier).



Positively charged ions are attracted to the SEM by its negative voltage which is provided by a high voltage power supply (up to 3kV). When an ion hits the SEM some of them knock an electron out of the surface. The SEM is coated with a resistive coating creating a potential gradient which attracts the electron down the SEM. As the electron bounces down the SEM it knocks more electrons from the surface resulting in a pulse of electrons at the end of the SEM.

Each ion produces a single pulse which is amplified in the RF head and then counted in the Interface Unit.

If the signal is too big the SEM will be damaged. A SEM has a limited lifetime, which is largely determined by the number of ions that hit its surface – its lifetime can be measured in the total number of pulses it counts. If it is exposed to a large signal its lifetime will be reduced. As the multiplier ages the amplitude of each pulse gets smaller. To be counted a pulse has to greater than the *discriminator* threshold. The pulse height can be increased by increasing the voltage across the SEM, the *multiplier* voltage. The correct operating voltage for the SEM is determined by measuring a peak in RGA mode and scanning the *multiplier* voltage.



The correct operating point for the multiplier is at the “knee” in this curve. At this point all the pulses are above the discriminator threshold. Beyond this point the signal continues to rise because of increases in the efficiency of converting ions to electrons.

The multiplier should not be operated above the knee because it reduces the life of the multiplier by producing excessive electron cascades.

The multiplier should not be operated below the knee because although this reduces the count rate it does not increase the life of the multiplier. The same number of ions are hitting the multiplier but more of the pulses are below the discriminator threshold and are therefore not counted, but the ions still damage the multiplier surface.

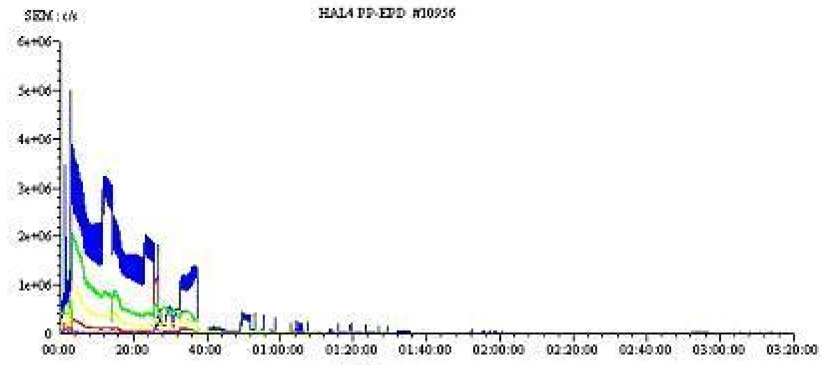
To protect the multiplier the signal should be reduced by other means, not by reducing the multiplier voltage.

The SEM may also be damaged by operating at too high a pressure in the analyser. The system should not be vented unless the multiplier voltage is zero.

Even in normal use the multiplier will gradually age. Periodically the multiplier voltage must be adjusted upward. As well as the mass alignment, the operating multiplier voltage should be checked regularly as part of the Preventative Maintenance schedule.

Eventually the SEM will approach its maximum operating voltage (3kV) and the multiplier will need replacing. This should be scheduled before this limit is reached as it involves performing a service-exchange of the entire probe assembly and its matching RF head.

Because the SEM is an expensive component and because replacing it is disruptive every effort should be made to conserve the SEM's lifetime by avoiding exposing it to excessive signals of more than 500,000 c/s.



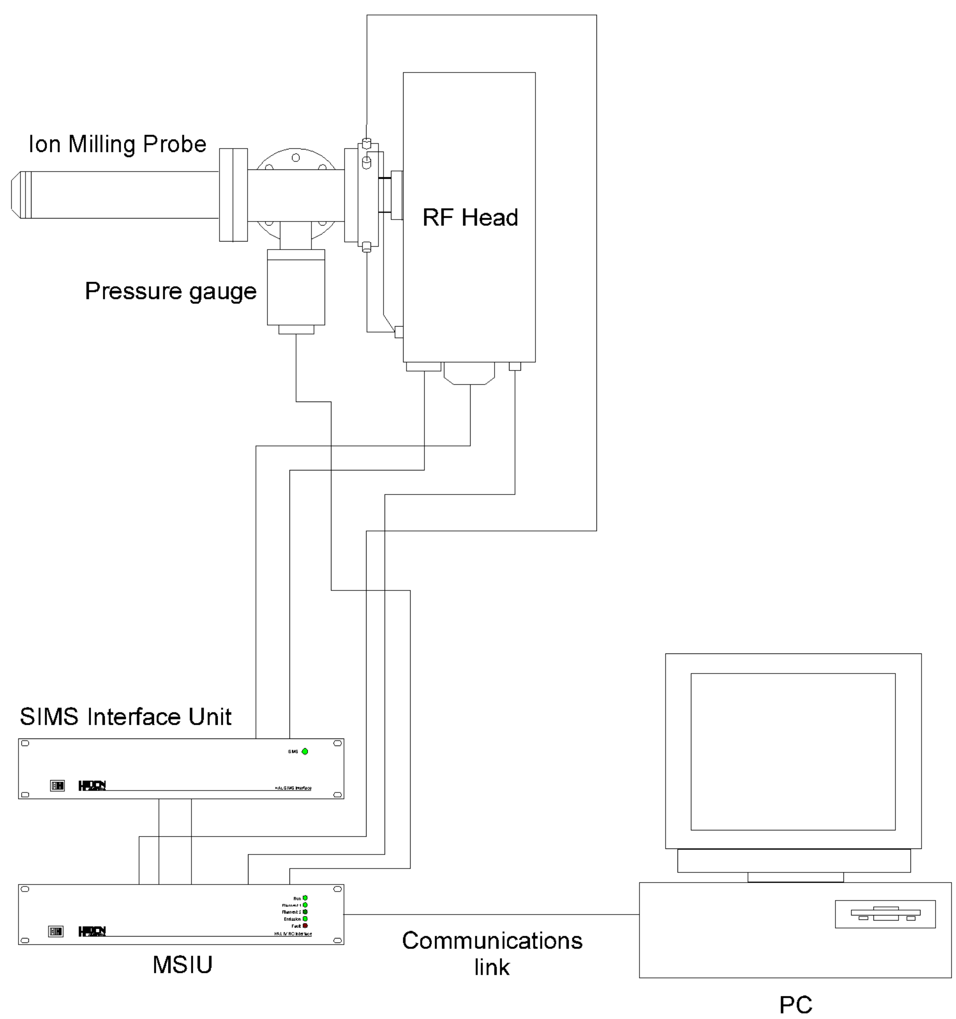
Loss of sensitivity due to exposure to large signal

Exposure of this SEM to very high count rates shifted its operating voltage by 600V in 2.5 hours of operation.

1.3. Summary of Important Points

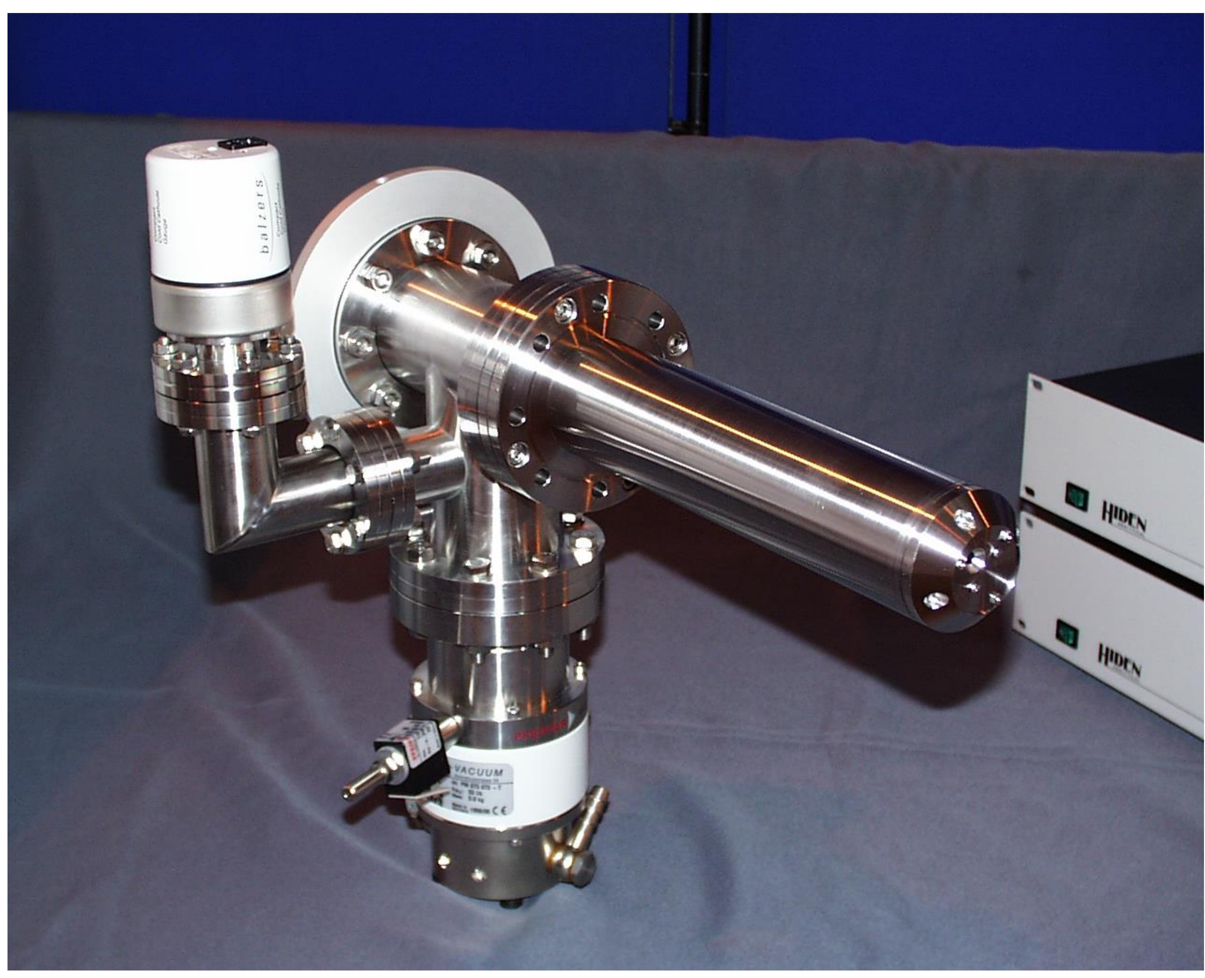
1. RF head and Analyser must always be kept together as a matched pair.
2. Use the isotopic mass of an element not its Atomic Weight.
3. Multiplier Voltage and Mass Alignment should be checked during PM
4. Excessive signal shortens SEM life.
5. Don’t reduce the multiplier voltage to reduce the signal.

2. The IMP-EPD System



The complete IMP system comprises of the following components:

- Mass Spectrometer Interface Unit (MSIU)
- Secondary Ion Mass Spectrometer (SIMS) Interface Unit
- Radio Frequency (RF) Head with Amplifier
- Ion Milling Probe
- Interconnection Cabling
- PC running MASsoft
- and Script Interpreter software.



Ion Milling Probe Analyser

- RGA ioniser
- Parallel plate energy filter
- Transfer optics
- Quadrupole mass filter
- SEM detector

The HAL Parallel Plate Ion Milling Probe Endpoint Detector (IMP-EPD) is a quadrupole mass spectrometer system configured with integral parallel plate energy filter, ion optics and an ion source for RGA (Residual Gas Analysis).

The assembly consisting of the orifice plate, cover tube containing the Quadrupole mass spectrometer, housing with pump flange and flange with radial and axial feedthroughs is termed the “analyser”, or sometime the “probe”.

The orifice admits ions to the Mass Spectrometer analyser. A restrictor plate may be attached, using the 2 screws (arrowed), to reduce the size of the orifice.

A pump maintains the analyser at a lower pressure than the chamber. Without a restrictor plate the pressure in the analyser will be approximately $1/50^{th}$ of the pressure in the chamber (this will depend on the capacity and efficiency of the analyser-housing pump).

The maximum operating analyser pressure should be $5x10^{-6}$ Torr, giving a maximum chamber pressure of about $2.5x10^{-4}$ Torr. Operating at a higher pressure will damage the SEM detector. The analyser should be protected by a pressure trip set to no more than $8\ x10^{-6}$ Torr.

If the chamber pressure is > $2x10^{-4}$ Torr then a restrictor plate must be fitted to ensure that the analyser pressure is < $5x10^{-6}$ Torr.

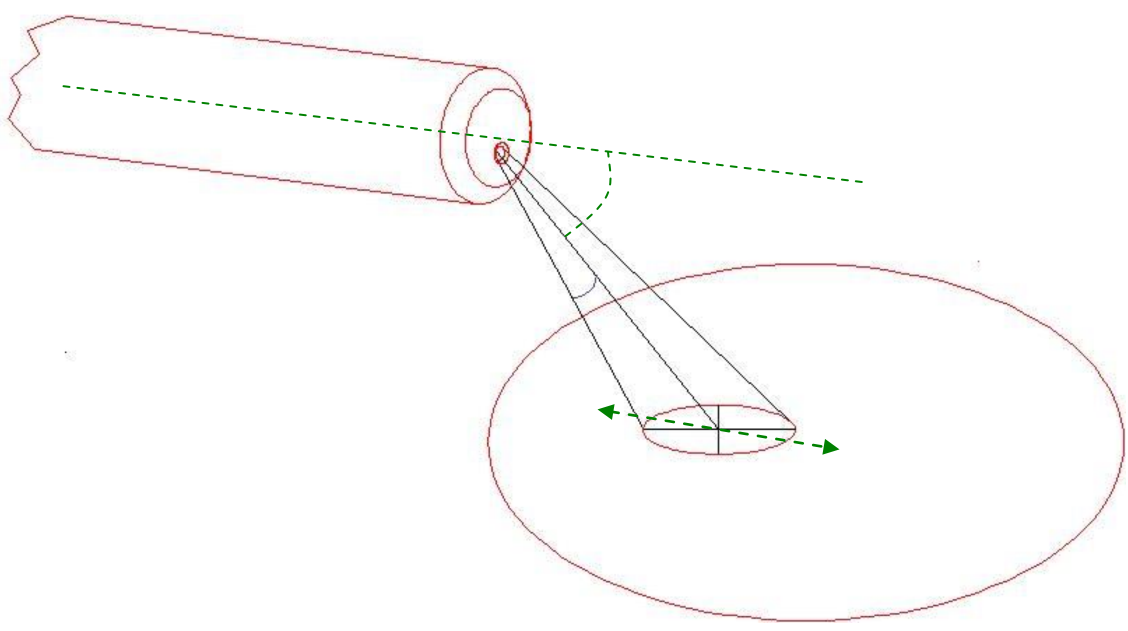
If the chamber pressure is $5x10^{-4}$ Torr then use the 2mm restrictor plate.

A restrictor plate may also be used to reduce the signal to prevent the SEM being exposed to count rates > 500,000 c/s.

The orifice is 7.5mm below the central axis of the probe, nearer to the lower plate. This means that ions enter at an angle of 30 below the central axis; A negative voltage on the lower plate attracts the positively charged ions, and a positive voltage on the upper plate repels them, so that they are deflected into

the quarapole mass filter. The voltage required to deflect the ions will depend on their mass and velocity (energy) and on the angle at which they enter.

This gives the analyser a “cone of acceptance” at a nominal 30 degrees below the central (z) axis:



It is therefore essential that when the analyser is installed that the orifice should be correctly aligned with the centre of the wafer. Adjusting the upper and lower plate voltages can compensate to some extent, moving the centre of the cone along a path parallel with the central axis.

The analysers are usually supplied so that when the RF head is vertical (Mid-point between MHV radial connectors 1 & 8 at top) the probe is correctly aligned. The pump may either be above or below the analyser depending on the configuration.

The relationship of the flange and radial feed-throughs to the upper and lower plates (and hence to the orifice) is fixed; it is marked on the flange body with an engraved arrow.

If, for any reason, it is required to rotate the analyser with respect to the pump housing then ensure that you follow the procedure in appendix X. If this procedure is not followed the Quadrupole filter assembly may be twisted. A twisted Quadrupole will exhibit poor peak shape and split or multiple peaks; it must be returned to the factory to be dismantled and re-assembled.

RF Head

- Signal conditioning electronics
- RF power supply (for the quadrupole mass filter)

The RF head provides the RF power to drive the quadrupole analyser and amplifies the signal from the SEM detector.

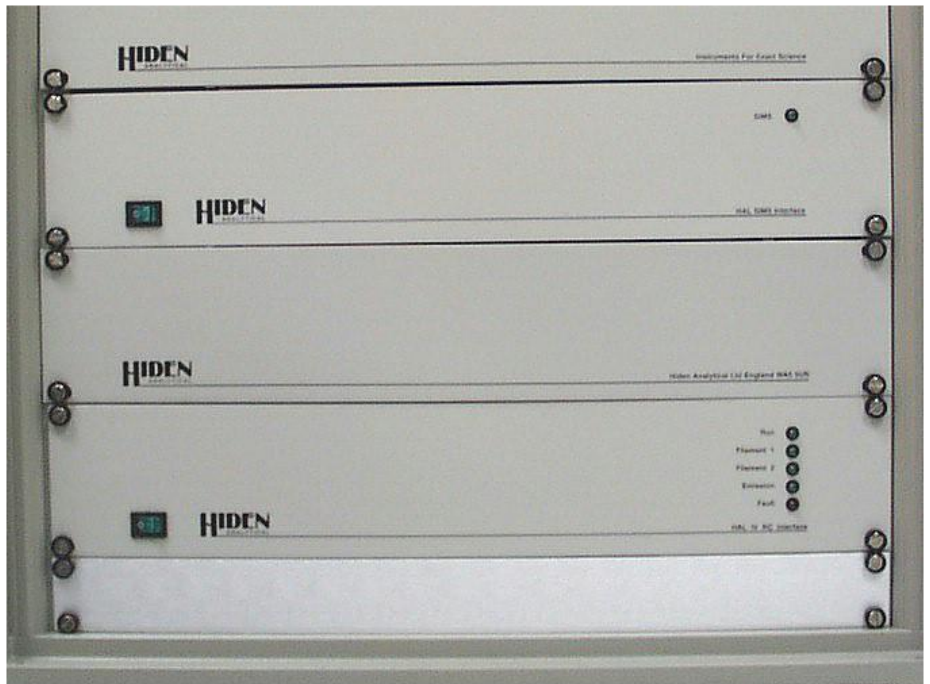
The RF generator in the RF head is matched to the capacitance of the analyser, which varies slightly from unit to unit, therefore analysers and RF heads are supplied in matched pairs. If an analyser is exchanged the RF head must be exchanged too. Matched pairs are identified by yellow labels on the analyser and RF head bearing the analyser serial number,.

If the RF head is not matched to the analyser the RF generator will overheat and the mass alignment will drift; the analyser may be unable to measure higher masses.

The procedure for matching an RF head to an analyser is described in section X.X.

The RF Head mounts on the probe base flange. A Torx™ screw on the RF head engages with a keyway on the 12 way feedthrough to ensure correct orientation; do not remove this screw.

The head should be pushed fully home onto the 12 way feedthrough to ensure that the springloaded centre signal pin makes contact. The head is held in place by two hex grub screws on the outer ring of the RF head.



SIMS Interface unit

- Switching between RGA and SIMS modes
- Voltage supply for optics and energy filter

The SIMS Interface contains power supplies that operate the Mass Spectrometer when it is in Secondary Ion Mass Spec (SIMS) mode.

The green mains power switch is located at the lower left of the front panel; the switch glows green when the unit is switched on. The SIMS LED indicates when the unit is operating in SIMS mode.

MSIU

- Control computer
- Communications Interfaces
- Mains power supply

- Electronics for internal ion source
- RF Head and SIMS Interface control signals

The Mass Spec Interface Unit (MSIU) contains a microprocessor that controls the Mass Spectrometer

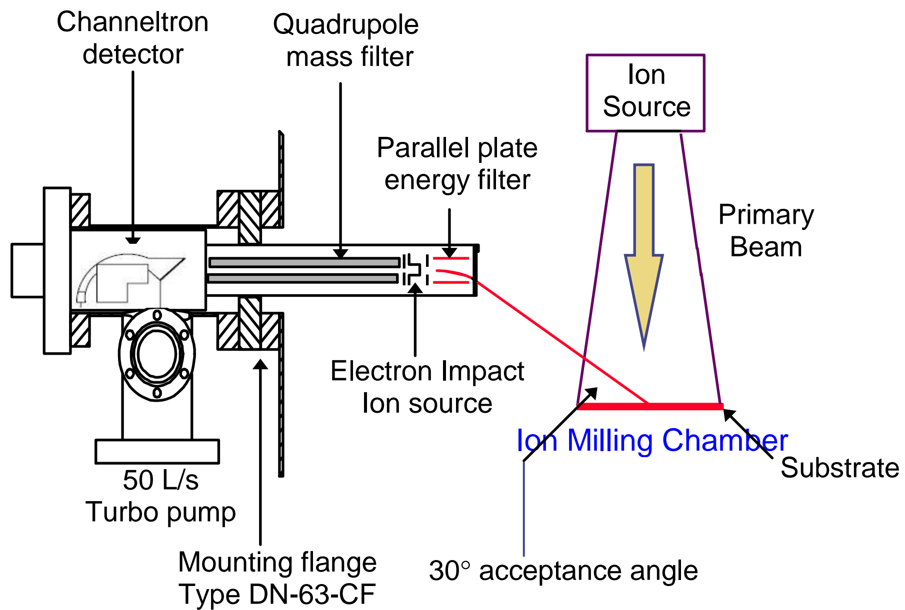
The green mains power switch is located at the lower left of the front panel; the switch glows green when the unit is switched on.
Instrument status is indicated by the four green and one red Light Emitting Diodes (LEDs) on the right-hand side of the panel.

The green “Run” LED will light when the **PowerUp** tool, or **Go** tool (green), on the **MASsoft** window Tool Bar, is selected. In this condition the analyser can apply power to the Probe and thus scan and acquire data.

The RGA ion source status is shown by the “Filament 1”, “Filament 2” and “Emission” LEDs which indicate the filament(s) selected and whether the required emission has been obtained. The “Emission” LED will flash if the selected filament has failed.

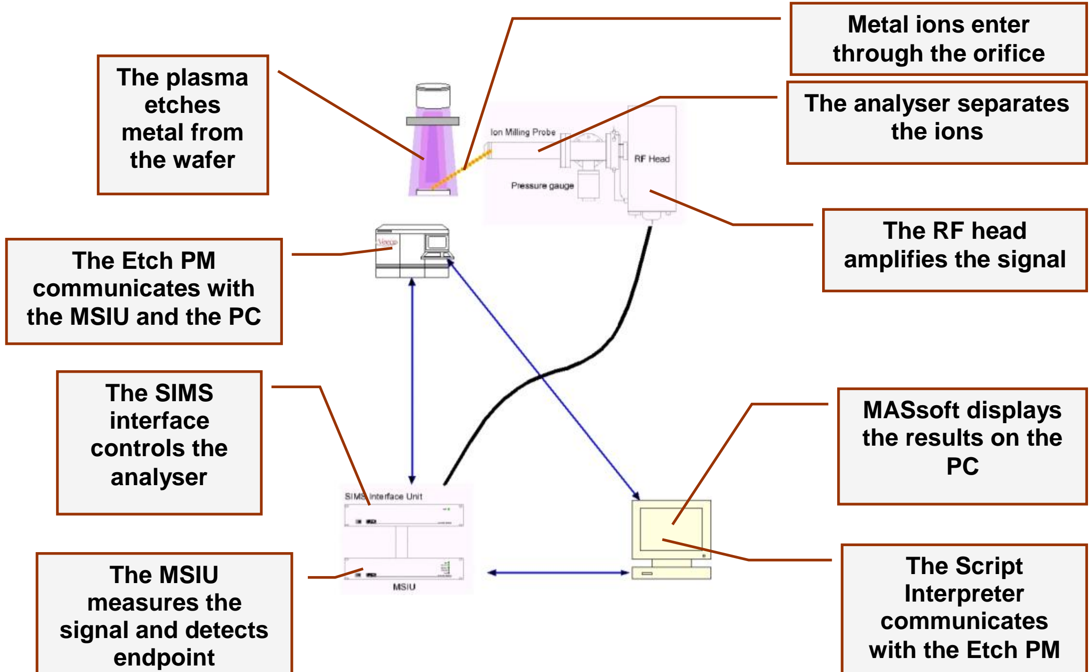
Internal faults may be indicated by the red “Fault” LED. The “Fault” LED will flash momentarily when the MSIU is switched on, see Section 4.5.

Ion Milling Probe



1. The plasma etches metals and other elements from the wafer and generates ions.
2. The energy of the ions depend on the plasma.
3. Some of the ions enter the probe through the orifice.
4. The orifice is off-axis, that is it is not in the centre of the probe
5. The ions enter the probe at an angle of 30°, therefore the probe must be positioned so that this angle points to the centre of the wafer.
6. The ions are turned through 30° by deflector plates. the voltage required on these plates depends on the mass and energy of the ions. The ions are focused by other "lenses" into analyser. The analyser lenses are driven by the SIMS interface.
7. The analyser filters the ions according to their mass. It can be set to only allow ions of a specified mass through, all other masses are blocked.
8. The detector is a SEM. It multiplies the signal of each ion that goes through the analyser into an electrical pulse. separates and measures the different metals.
9. The signal is amplified in the RF head and measured in the MSIU

IMP System



When the Process Module's recipe requires a process step to end by endpoint it sends a command over a serial (RS232) connection from the PM to the PC. The command specifies an endpoint script

The Script Interpreter software receives this command, then opens and runs the endpoint script file. The Script file instructs MASsoft, also running on the PC, to open and run a Template file.

The Template File contains the voltages required by the IMP-EPD electrodes, the masses to be analysed and the method to be used to determine endpoint. These settings are transmitted to the MSIU.

When the settings have all been sent to the MSIU the Script Interpreter sends an "ACK" (acknowledge) message to the PM. If an error is encountered a "NAK" (Negative Acknowledge) message is sent.

If the PM receives a "NAK" it will re-try the command. If it repeatedly fails an error will be logged and processing will be stopped.

If it receives an "ACK" the PM will proceed with processing the wafer.

When the PM opens the shutter it sends a START STEP message to the Script interpreter. The step number must match the step number in the Script Interpreter script for processing to continue.

The PM also sends an I/O signal directly to the MSIU, a 2s start pulse. When the MSIU receives this it starts acquiring data.

At this point some scripts check that the pressure in the analyser is OK ($< 5x10^{-6}$ Torr setpoint) and will return a NAK to the PM if it is not.

When the MSIU starts acquiring data the Script Interpreter returns a STEP STARTED message to the PM.

If while acquiring data the shutter is closed , the PM send a signal to the MSIU and data acquisition is suspended until the shutter opens.

The MSIU then monitors the acquired data to determine endpoint, this is usually the end of the last layer or the beginning of the substrate.

When endpoint is found the MSIU closes a relay, this is a signal to the PM to stop etching. If the IMP-EPD fails to find endpoint then etching continues until the maximum step time is reached, at which time the PM can (depending on PM.INI settings) log an error and stop further processing.

2.1. Detecting the Endpoint

The Ion Milling Probe monitors secondary ions generated in the etch process. Each layer will produce ions of different mass to charge ratios.
By monitoring the signal intensity of secondary ions due to material from a particular layer the end point can be determined.

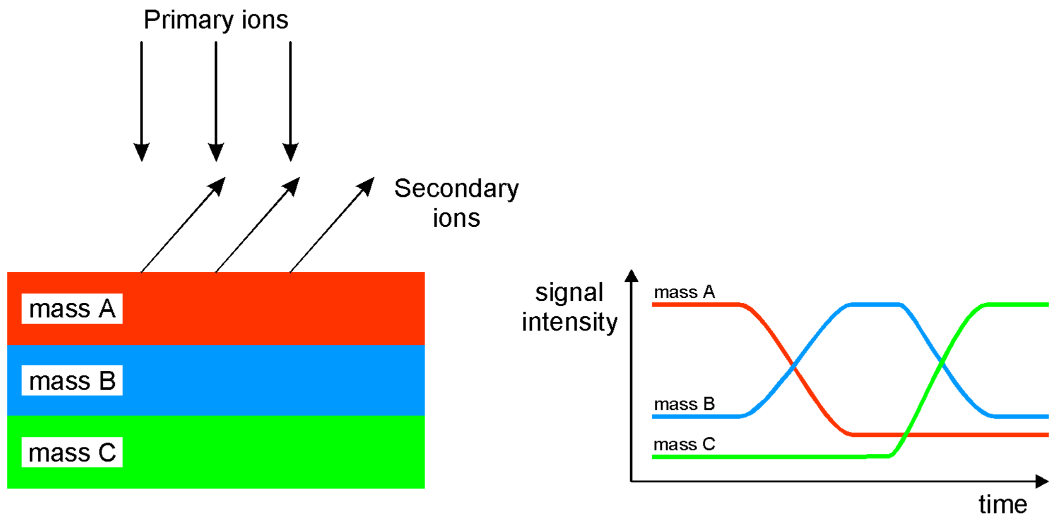


Figure 2.2 Secondary ion signal intensity

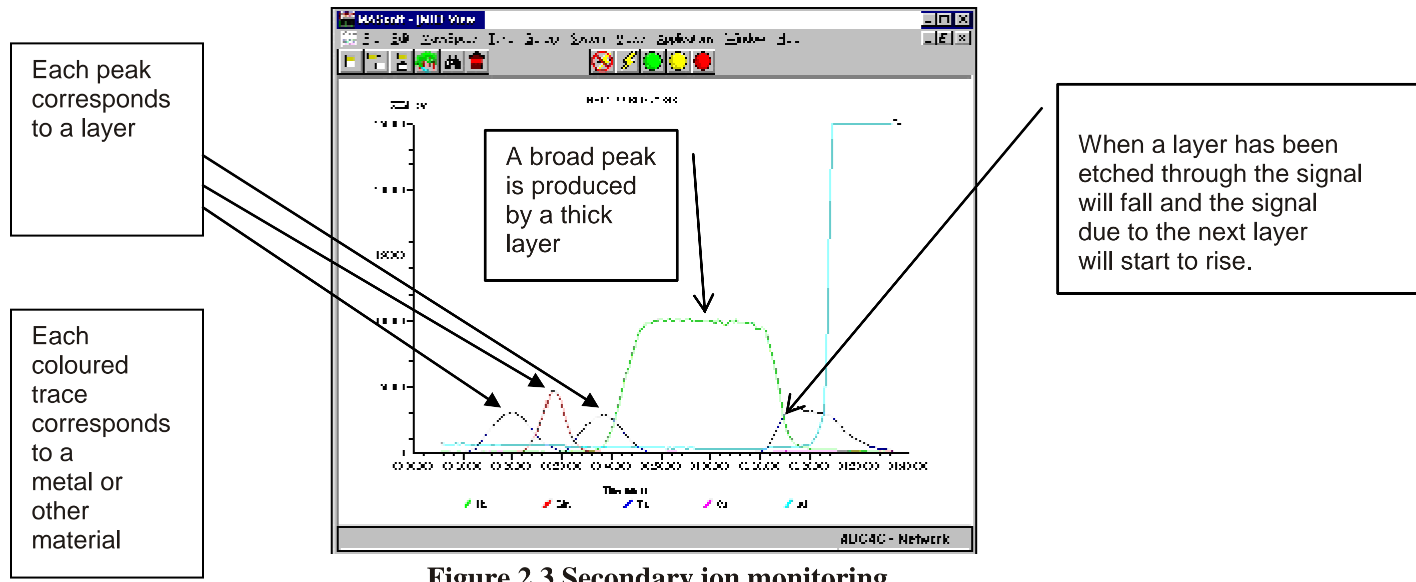


Figure 2.3 Secondary ion monitoring

The width of a peak in the trace indicates the length of time taken to etch through the layer. If the etch rate is known the thickness of the layer can be determined.

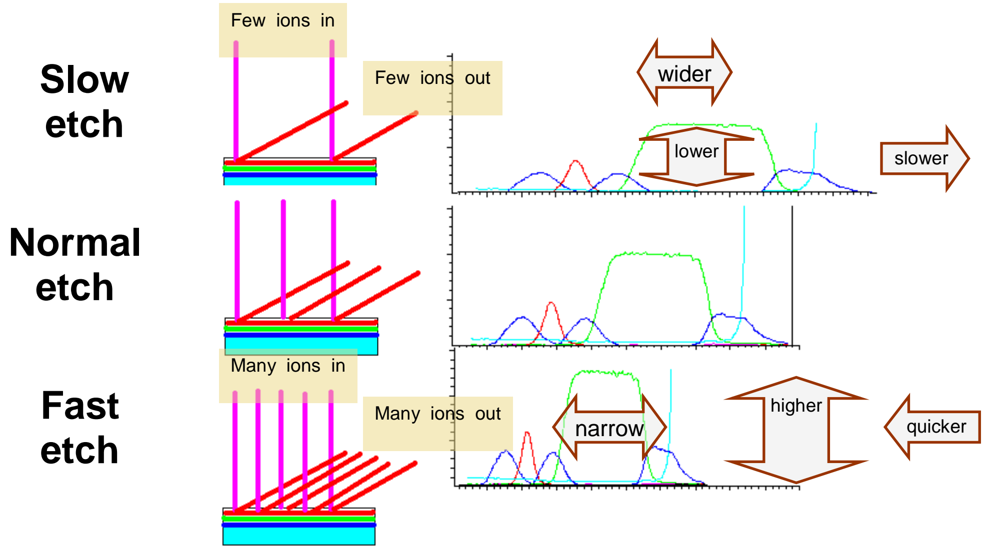


Figure 2.4 Secondary ion monitoring

The width of the peak is proportional to the thickness of the layer. The faster the etch the bigger the secondary ion signal, the slower the etch the smaller the signal.

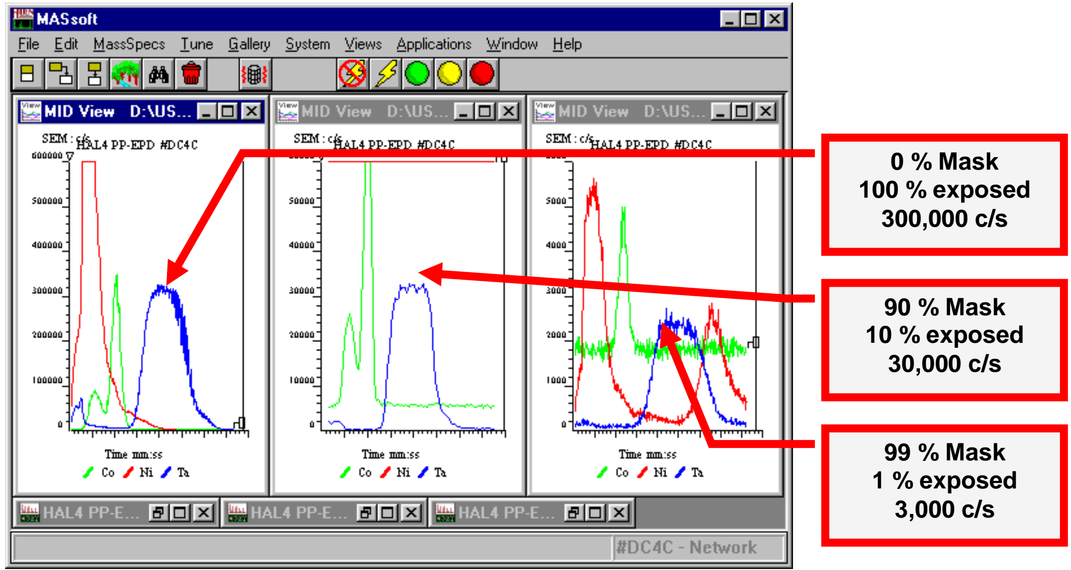


Figure 2.5 Wafer masking affect

The amount of wafer mask will also affect the signal intensity. Ten times more wafer is exposed to the primary ion beam with a 90% mask than with a 99% mask. So, the signal intensity due to the secondary ions will be ten times greater. **It is not the % mask that counts but the % exposed area.**

The type of metal being etched will also affect the signal intensity. The mass spectrometer is more sensitive to some metals than others.

The tuning of the instrument will also affect the signal intensity which is why each wafer type needs its own "template" file.

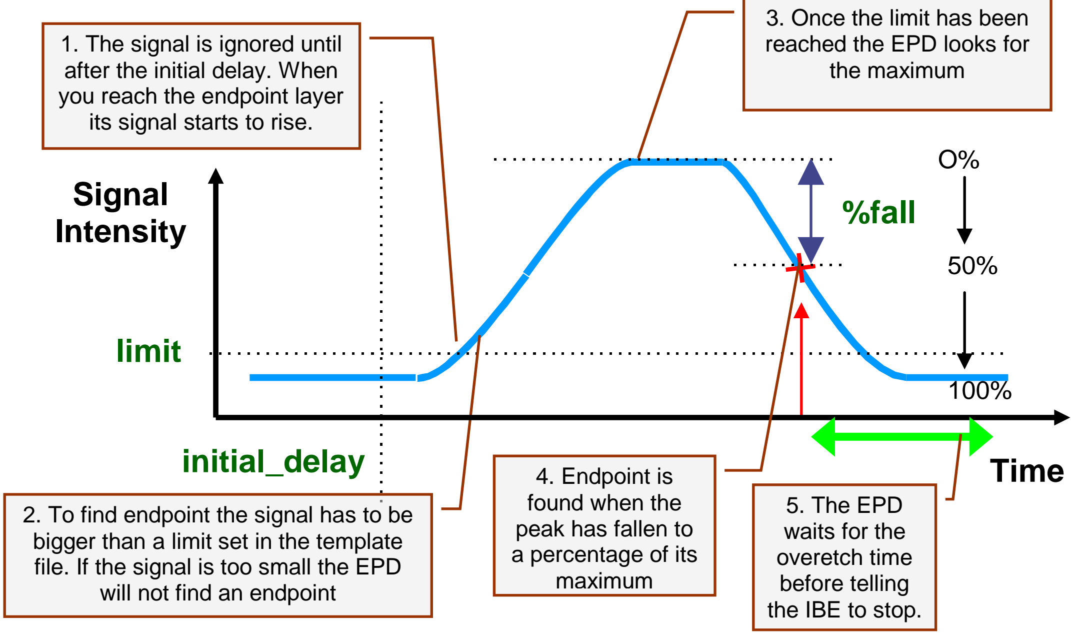


Figure 2.6 End point detection

Figure 2.6 shows the basic falling-edge endpoint (method 4) . Other methods allow the endpoint to be found on a rising edge (either above the limit value, or relative to a previous peak) and to do layer counting (e.g. end on the second Ta layer).

Methods that use relative peak height, like method 4 , are to be preferred over methods that use an absolute peak height (like method 1 – rising edge, above limit value) because the peak height may vary, either due to changes in etch rate as shown in figure 2.4, difference in mask as shown in fig 2.5 or due to the gradual decrease in the sensitivity of the SEM as it ages. If a method that uses absolute peak height is used you will not be able to use the same endpoint conditions for a masked production wafer and an unmasked qualification wafer.

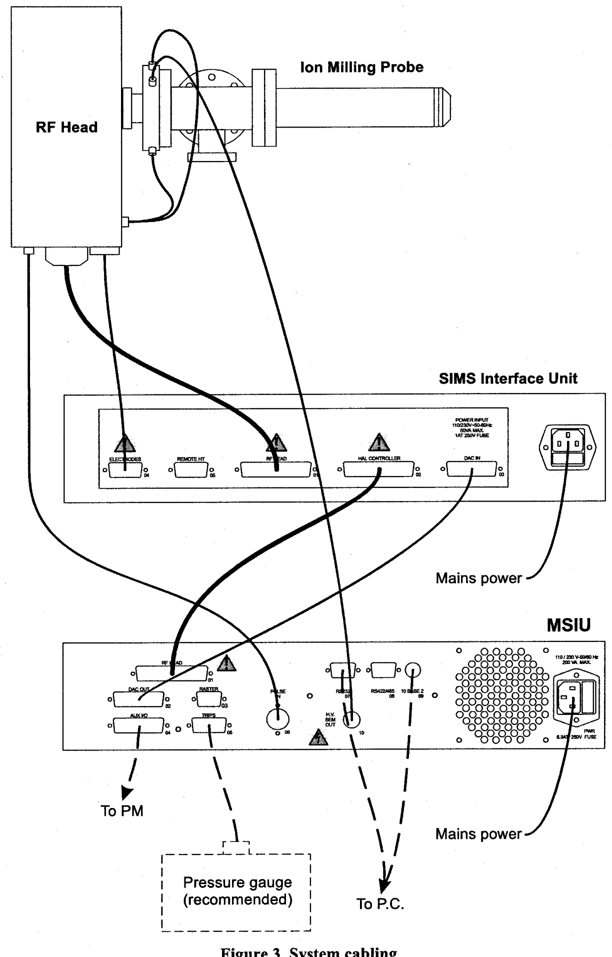


Figure 3 System cabling

3. IMP-EPD Software

3.1. Introduction

The Hiden IMP-EPD is controlled by two programmes:

- MASsoft – Controls the Mass Spectrometer and acquires endpoint data during the etch.
- Script Interpreter – Interfaces MASsoft to the PM

MASsoft is a general purpose programme that can be used to control any instrument in Hiden Analytical's range of Mass Spectrometers.

This manual will cover those aspects of the MASsoft software relevant to its use as an endpoint detector. For information on other capabilities of MASsoft please refer to the MASsoft Professional User Manual HA-085-067.

The End Point Detector Script Interpreter User Manual HA-085-061 describes the capabilities of the Script Interpreter (SI) software.

MASsoft performs the following functions:

- Endpoint detection in conjunction with a "Template" file.
- Tuning – adjustment of the Mass Spectrometer electrode voltages.
- Maintenance and diagnostic functions.

This section considers the software with regard to its use as an Endpoint Detector. The other functions are described elsewhere in this manual.

3.2.Experiment Files

MASsoft holds data, and the settings used to acquire the data, in files called "Experiment" files.

In fact all MASsoft Experiment files are sets of five files:

- **The .EXP file – the master index file.**
- **The .SCN file – holds the scan structure.**
- **The .ENV file – holds environment values**

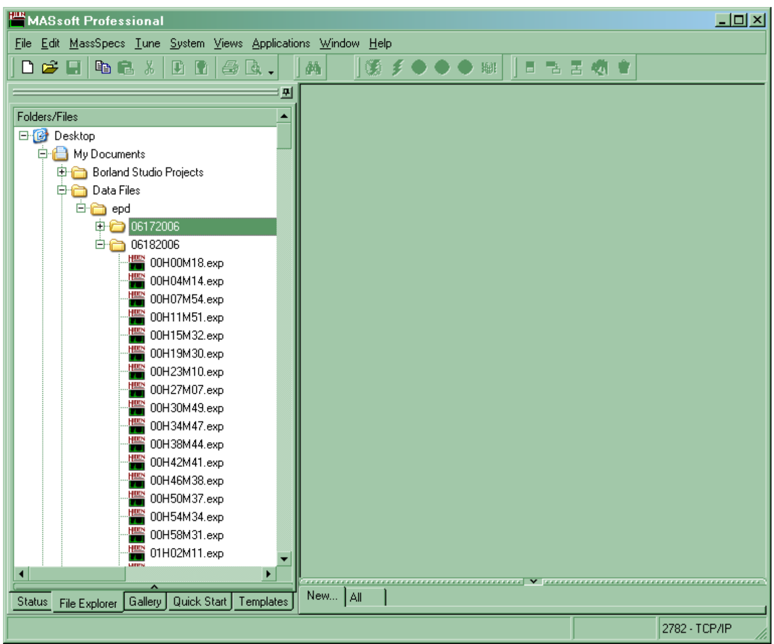
- **The .ANN file – holds information about views (.ANN stands for annotation)**
- **The .DAT file – holds data.**

MASsoft treats all five constituent files as if they were a single entity. To view data all five files are required (though the .ANN file can be re-created). When moving or copying data (e.g. for backup purposes) all five files must be moved or copied.

MASsoft does not distinguish between settings and data files. Experiment files are initially created empty, without data. Empty experiment files just contain settings but still require a .DAT file, albeit a very small one (5 bytes). Data files are Experiment files that contain data

Any experiment file may be run, empty or with data. When the file is run the settings are sent to the Interface Unit (IU). The option is given to over-write the existing file or to create a new file; if a new file is created the settings are copied from the existing file.

The most convenient way to manage experiments files is to use MASsoft's File Explorer tab.



MASsoft's File Explorer tab only shows the main .EXP file. Moving, copying or deleting the .EXP file also moves, copies or deletes the other constituent files. In addition the File Explorer tab treats .LOG and .CSV files with the same name as the .EXP file in the same way.

The .EXP file itself is only an index to the other files. The .EXP file (or the .DAT file) on its own is not sufficient to view the data. If you send data you must send all 5 files; if you are sending the files by e-mail you should send them in a compressed (zip) file because some e-mail clients may embed one or more of the constituent files as a text file.

NOTE: When sending data to Hiden please send zipped experiments files not screen shots.

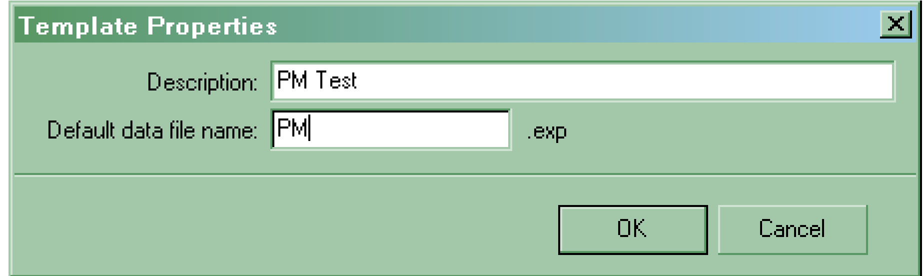
Sending the zipped experiment file is preferable to sending a captured screen shot because the experiment file contains the environment settings used to acquire the data and because the full capabilities of MASsoft may be used to view the data, for example to zoom in on part of the data. Experiment files are also usually much smaller than screen shots.

NOTE: A MASsoft data file reveals a lot of information about the wafer being etched. It shows the material in the stack; from the width of the peaks the relative thickness of the layers can be deduced. Care must be taken not to disclose proprietary information.

3.3. Template Files

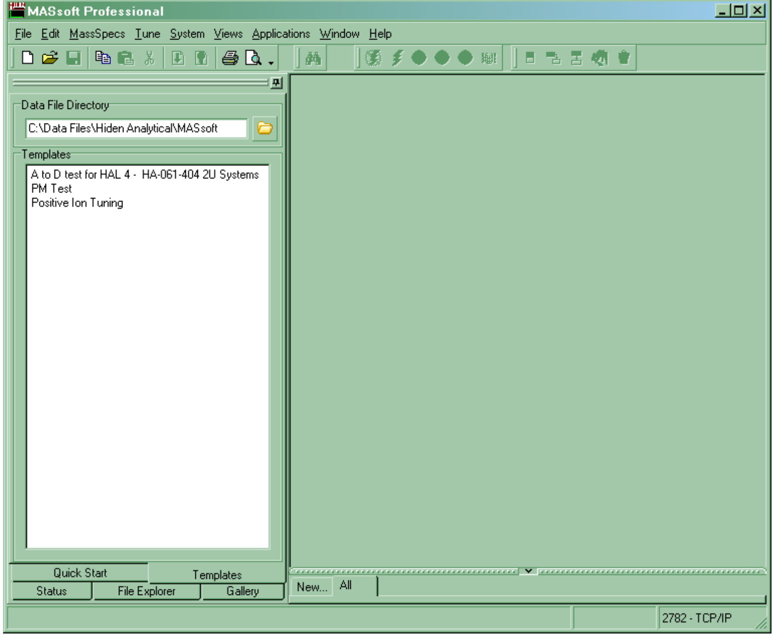
An Experiment File that contains the settings required for a particular analysis is called a Template File; usually the file is saved without data.

The **Save as template** command in the File menu allows you to save a file as a template.



Standard template files are saved to a template folder as a combination of description and data file name.

When a template has been saved it can be run from the Template Tab



Double click on the template's description to run it. A data file will be saved in the **Data File Directory**. Each run will generate a sequentially numbered file based on the **Default data file name** in the Template's properties.

3.4. EPD Template Files

An EPD Template file is an Experiment file that contains the settings , scan and control sequence needed to detect the endpoint of an etch step.

EPD Template files should be saved in a different folder from standard Template files so that they do not appear in the Templates Tab. EPD Template files are not associated with a data file name in the same way as the templates in the Templates tab.
The folder for used EPD Templates is specified by the Script Interpreter in its Experiment Parameters dialog from the Preferences menu.

Do not use the **Save As Template** command to save EPD Templates. EPD Templates should be saved using the standard **Save** or **Save As** commands.

3.4.1. Overview of an EPD Template File

The Scan Tree – The Scan tree specifies the masses of the ions that are to be measured. These correspond to the materials in the wafer stack.

The Instrument Environment – Holds settings that are to be used in common by all endpoint templates (Not strictly part of the Template file).– The Instrument Environment holds the current multiplier voltage. The “tuned” values for the Mass Spectrometer electrode voltages are saved to the Instrument Environment after the “Autotune” procedure.

The Global Environment – Holds the settings for the endpoint method, determines when the endpoint is found. Holds any Mass Spectrometer electrode voltages that have been optimised for the particular wafer stack.

The Local Environment – Holds Mass Spectrometer electrode voltages that have been optimised for a particular ion. Use to adjust the instrument’s sensitivity to a specific layer in the wafer stack.

The Event Sequence – Contains the control sequence that implements endpoint detection. The event sequence is responsible for starting and stopping the scan in response to signals from the PM. It monitors the data and signals to the PM when endpoint is found.

3.4.2. The Scan Tree

The Hiden EPD determines the endpoint of the etch by monitoring the secondary ions produced by the ion mill process.

The Mass Spectrometer monitors several secondary ions by rapidly scanning the mass filter. The display is usually set up to show an ion that characterises each layer. However only one ion is used to determine the endpoint; a second ion is sometime used as a reference peak.

The sequence of masses to be measured is defined in a “Scan Tree”.

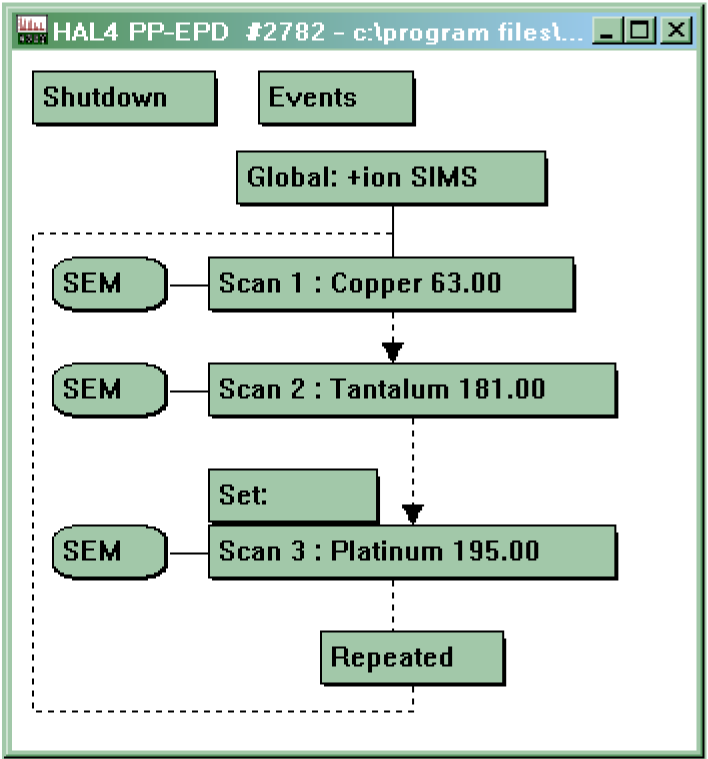


Fig. x A Scan Tree

The scan in figure x measures three ions, Copper at 63 amu, Tantalum at 181 amu and Platinum at 195 amu. The scan measures the three ions in sequence. First the mass filter is set to 63 amu and a measurement taken using the Pulse Ion Counting (PIC) SEM detector, then the filter is set to 181 amu and another measurement is taken using the PIC SEM detector; finally the filter is set to 195 amu and a measurement is taken.

The Quadrupole mass filter can only pass one mass at a time, so readings are consecutive. By default each reading takes 110ms; this value can be adjusted to take longer readings to reduce the noise on small signals, or shorter readings when monitoring ions from layers above the endpoint layer.

The Platinum scan is shown with a “Local environment” attached. This allows Mass Spectrometer electrode voltages that have been optimised for the measurement of platinum to be used, or for the resolution to be reduced to increase the instrument sensitivity.

When all the ions have been measured the cycle repeats itself.

As many masses as required may be added to the scan tree.

3.4.3.Environments

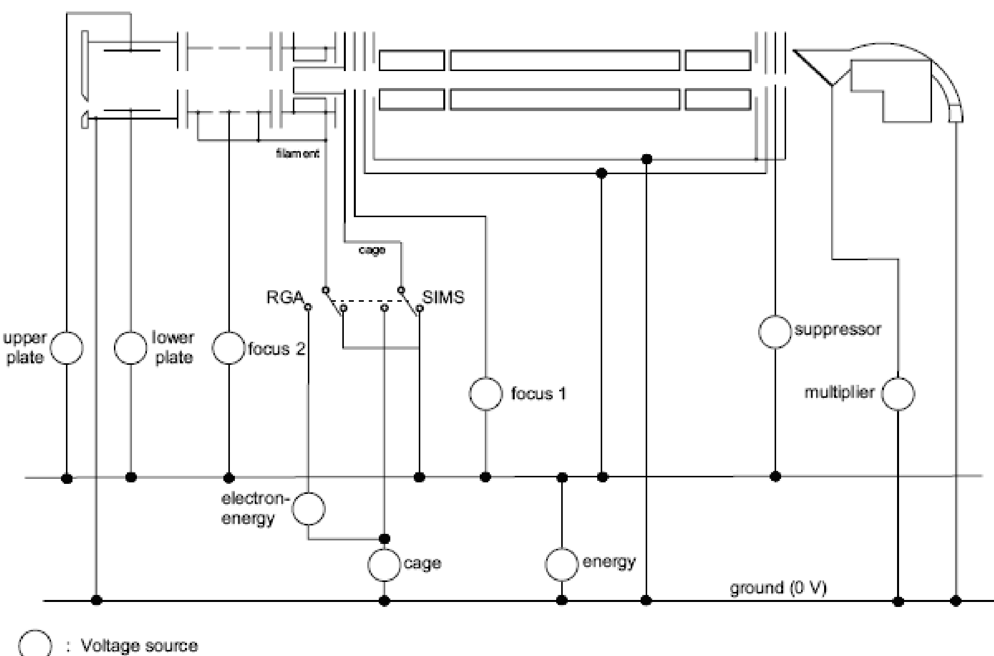
An environment is a collection of variables and device settings. These can broadly be split into two categories:

1. Analyser control variables. Hardware device settings, mainly associated with power supplies that drive the electrodes of the lenses that comprise the ion optics of the analyser.
2. Endpoint detection variables.

3.4.3.1. Analyser control variables

The Analyser control variables are grouped according to their function into five groups; Filter, Source, Quad, Detector and Other They are defined in Sections 3.4.3.2 to 3.4.3.6.

These are best understood in relation to the configuration of the Parallel Plate IMP.



3.4.3.2. Filter group variables

focus1 focuses the ion source output into the quadrupole mass filter entrance aperture.

suppressor the **suppressor**'s main function is to stop electrons reaching the detector; it also acts as a lens, helping to focus the ion beam into the detector. The suppressor should always be set to -100V

focus2 focuses the beam from the Parallel Plates energy filter into the ion source. A negative bias is normally applied.

energy sets the axial potential of the quadrupole mass filter and defines the energy of the ion which is analysed.

upper plate
lower plate The voltage difference between the **upper plate** and **lower plate** determines the transmission level of the probe. The lower this voltage difference the greater the energy resolution but the lower the signal level. The **upper plate** is normally positively biased with respect to the **lower plate** in order to deflect ions towards the probe axis.

*As they are positioned in front of the ionisation source, the **upper plate**, **lower plate** and **focus 2** have no effect in RGA mode.*

3.4.3.3. Source group variables

The source group contains all the parameters associated with operation in RGA mode, i.e. filament **emission**, **cage** potential and **electron-energy**.

*These controls have no function in SIMS mode. In SIMS mode the **cage** and filament are connected to the **energy** supply by a relay.*

electron-energy sets the energy of the electrons emitted by the ion source filament. The normal operating voltage in RGA mode is 70 V. **Electron-energy** should not be set below 5 V in order to avoid filament damage.

emission The current due to electrons emitted from the filament and collected on the ion source cage mesh is set by **emission** (not shown above). The normal operating **emission** current in RGA mode is 20uA. The filament current is controlled to ensure that this electron current is maintained.

cage When in standby mode, **cage** is set to -5 V to contain ions within the ion source. During scanning, the cage voltage is set to the value of this variable. It determines the energy at which ions, created in the ion source (normally RGA ions), transit the mass filter.

3.4.3.4. Quad group variables

resolution sets the analyser's high mass resolution; it is displayed on an arbitrary ±100% scale.

delta M is displayed on an arbitrary ±100% scale; it sets the low mass resolution.

3.4.3.5. Detector group variables

CAUTION
The voltages applied to the SEM detector must be selected with care, otherwise the detector may be damaged.
The detector is a continuous dynode SEM.

multiplier sets the voltage across the SEM and consequently determines the gain of the device. **Multiplier** should be set very carefully. If the voltage is set too high with a high beam current, or high gas pressure, permanent damage to the SEM may result. Refer to Chapter 3.

discriminator sets a voltage level on a comparator connected to the pulse amplifier. If the pulse height is more negative than the discriminator level then the pulse is counted. The **discriminator** level should be set below the most negative level of the background noise to prevent false counts. During normal operation it is set at -10%.

3.4.3.6. Other group variables

mass sets the Quadrupole mass filter to allow the specified mass to be measured. Only used when the scan tree is scanning a lens other than mass. For example when auto-tuning you set mass to 63 to tune on Copper.

mode-change-delay
is the delay when switching to the current mode. In RGA mode the **mode-change-delay** allows the filament's emission to stabilise before starting measurements.

3.4.3.7. Endpoint detection variables

Endpoint detection variables are all in the endpoint group.

The original endpoint variables used by older template files are.

- %fall
- %over-etch
- falling

- initial-delay
- slope

The **falling** variable is retained for backward compatibility with older templates. In new templates the **method** variable is used in instead.

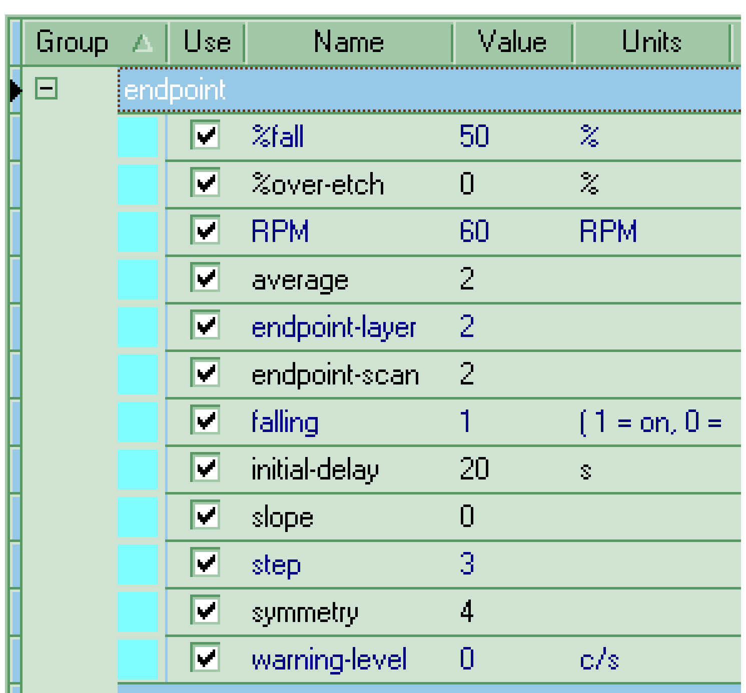
There are eight new endpoint variables:

- RPM
- Average
- Endpoint scan
- Method
- Reference scan
- Step
- Symmetry
- Warning level

The new variables are used by templates based on the “methods” template. Older templates (e.g. 2points and rotate) will still run, but will ignore the new variables.

3.4.3.8. Endpoint group variables

.



Group	Use	Name	Value	Units
endpoint				
	✔	%fall	50	%
	✔	%over-etch	0	%
	✔	RPM	60	RPM
	✔	average	2	
	✔	endpoint-layer	2	
	✔	endpoint-scan	2	
	✔	falling	1	(1 = on, 0 =
	✔	initial-delay	20	s
	✔	slope	0	
	✔	step	3	
	✔	symmetry	4	
	✔	warning-level	0	c/s

3.4.3.9. Rising edge variables.

initial-delay The delay, in seconds, after the start of the run until end-point detection is enabled. This may be used to ensure endpoint detection ignores any layers above the endpoint layer.

slope Minimum 'slope' value for the rising edge of the endpoint layer. This value is the minimum difference required between the signals read in the current and previous (normally 5 cycles earlier) scan cycles before a trace maximum (and, therefore, an endpoint) will be detected. A suitable value for this parameter can compensate for noise or sample rotation.

limit A minimum intensity limit for the endpoint layer. Signals below this level are regarded as noise or background and are not used for endpoint detection.

3.4.3.10. Falling edge variables.

falling Set true (1) if the endpoint is to be a falling edge, otherwise set false (0). Falling edge detection is recommended as it allows a level relative to the layer maximum to be used (see **%fall**).

%fall Determines how far below the maximum the signal must fall before the endpoint is signalled.

3.4.3.11. Over-etch variables

over-etch-time
` The time, in seconds, after the endpoint is detected before the endpoint signal is set true. Determines how long the etch continues after the endpoint.

%over-etch Over-etch time as a percentage of the run time. This is the delay after the endpoint is detected before the endpoint signal is set true. It can compensate for varying etch rates.

max_over-etch
The maximum time, in seconds, that a percentage over-etch may take. This time will not be exceeded even if a calculated percentage over-etch time is longer

3.4.3.12.New method variables

endpoint-scan
the mass you want to endpoint on.

reference-scan
the mass you want to use as the 100% level or calculate ratios relative to, depending on the method.

endpoint-layer
used when there is more than one layer of an element . Specifies the layer to endpoint on.

method allows one template to handle multiple methods of endpointing: e.g. ratio, %fall relative to another peak

3.4.3.13.New Noise reduction variables

average set the number of cycles of data averaged for the endpoint and reference scans.

RPM
symmetry these can be used to calculate the time required for one revolution. This can be used to prevent endpointing on oscillations caused by rotation and to set the dwell time to minimise the oscillations.

3.4.3.14.Other new variables

warning-level the minimum peak height for the reference and endpoint masses

step used by the Script Interpreter to tell the EPD what PM Recipe step is running. (Formerly endpoint-layer was used for this purpose).

3.4.4. Modes

The Hiden IMP-EPD has three modes. Each mode has its own set of environment variables. Different values may be assigned to the analyser control variables in each mode of operation.

Shutdown In shutdown mode the lens power supplies are left in a safe state. The **multiplier** should be set to 0V to protect the SEM. The mass should be set to a low mass. The RGA ion-source is disabled.

The analyser and SEM will not be damaged if the system vents in Shutdown mode.

RGA **Residual Gas Analysis** mode is used for diagnostics and maintenance.
It analyses gases in the chamber. It should not be used when the Ion Beam is on. In RGA mode the ion-source is enabled.
The **multiplier** should be set to the current operating voltage.
Initially **energy** should be set between 0V and 0.5V. The **energy** may be adjusted between 0V and 2V to improve the peak shape in RGA mode.
electron-energy should be set to 70V and **emission** to 20uA.
focus1 should be set to -30V.

SIMS **Secondary Ion Mass Spectrometry** mode is used for endpoint detection. It analyses ions. It requires the Ion beam to be on, no signal will be obtained in the absence of the Ion Beam. The RGA ion-source is disabled.
The **multiplie**r operating voltage in SIMS mode should be set to the same value as in RGA mode.
energy, upper-plate, lower-plate, focus1 and focus2 should be “tuned” for maximum signal.

The endpoint detection variables are only used in SIMS mode, during end point detection. They only need to be defined in SIMS mode in EPD Template files.

3.4.5. The Environment Hierarchy

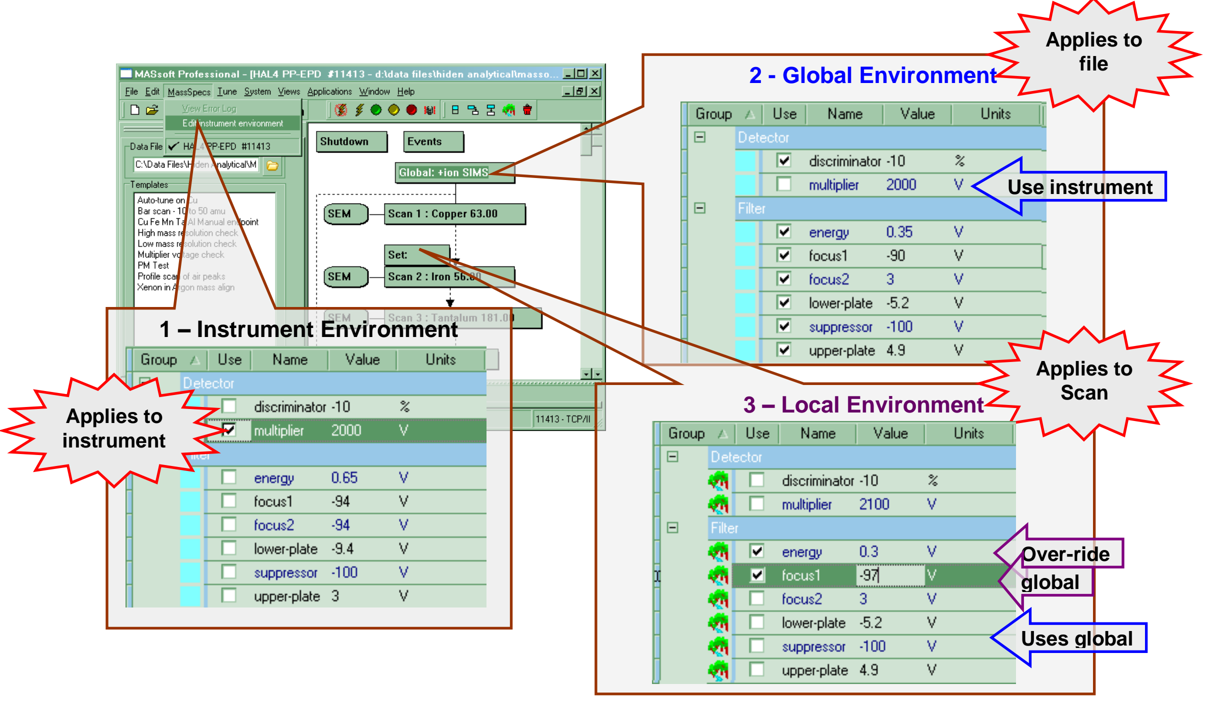
Environments exist in a hierarchy:

Instrument Environment < Global Environment < Local Environment

A value in the Global Environment takes precedence over the corresponding value in the Instrument Environment if its “Use” check box is checked in the Global Environment.

Likewise if a scan has a Local Environment then the value in the Local Environment takes precedence of the corresponding value in the Global Environment if its “Use” check box is checked in the Local Environment.

Environment Hierarchy



The Instrument Environment

Has values for Shutdown, RGA and SIMS modes.
Holds settings that are specific to the instrument.
Holds settings that are to be used in common by all endpoint templates.
Most of the Analyser Control variables should take their values from here.
Holds the current multiplier voltage.
Values for Analyser Control variables are saved in the Instrument Environment after auto-tuning.

The Shutdown Environment

Has values for Shutdown mode only.
Settings are specific to the file.
Will usually default to same values as in Shutdown mode in the Instrument Environment, so all “Use” checkboxes may be left unchecked.

The Global Environment

Has values for RGA and SIMS modes.
Settings are specific to the file
Default mode is defined here – should be **+ion SIMS** in an EPD Template file.
Holds the settings for the endpoint method, determines when the endpoint is found.
All Endpoint detection variables should have their “Use” checkbox checked.

Holds any Analyser Control variables that have been optimised for the particular wafer stack.
All other Analyser Control variables should have their “Use” checkbox unchecked

The Local Environment
Settings are specific to the scan to which it is attached.
Has values for one mode only, RGA or SIMS, depends on mode of scan – should be **+ion SIMS** in an EPD Template file.
Holds Analyser Control variables that have been optimised for a particular ion.
Must not contain any Endpoint detection values. All variables in the endpoint group must have their “Use” checkbox unchecked.

4. The PM Test File

4.1. Introduction

Maintenance of the IMP-EPD should be integrated into the normal tool maintenance schedule. During cleaning of the chamber, whilst the tool is vented, the probe should be visually inspected for etch damage and cleaned to ensure that the orifice is not blocked, as described in the Maintenance section of this manual.

The IMP-EPD PM check can conveniently be performed after the normal tool PM is complete, while the chamber is pumping down. It will not increase the time required for the PM.

The IMP-EPD PM check must be performed regularly to ensure that the correct multiplier voltage is being supplied to the SEM detector. The required voltage increases as the detector ages.

The IMP_EPD maintenance check consists of running the PM Test File. This file should be run after tool maintenance is complete, when the probe pressure reaches less than 1x10-6 Torr.

This file checks the response profiles for all of the EPD variables, including SEM detector and the mass alignment.

To maintain optimum conditions for the EPD, this file should be run at least once every month.

4.2. Saving the PM Test as a Quick Start Template

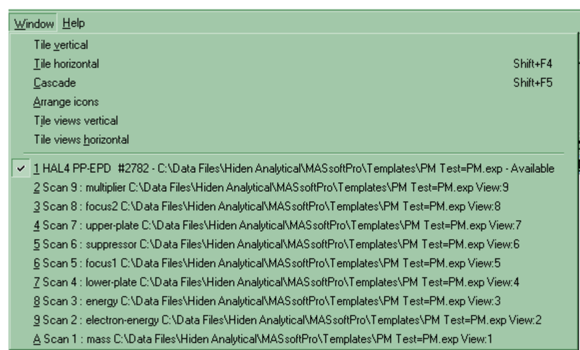
It is a good idea to create a PM Test entry in the Templates Tab in MASsoft. This procedure also checks that the multiplier voltage used during the PM Test is obtained from the Instrument Environment. It should be used to update PM files created with earlier versions of MASsoft or created on another instrument.

1. Start MASsoft on the EPD PC.
2. Select the Menu Bar File, Open command.
3. Navigate to the \Data Files\Hiden Analytical\MASsoft Pro\PM_TEST folder
4. If the file was created on a different instrument then convert the file by using the Convert tool on the tool

bar or by selecting File, Convert File from the Menu Bar.

5. If the file is locked unlock the file using the Unlock tool on the tool bar or by selecting **File, Unlock** from the Menu Bar.

6. Ten Windows will be displayed. The Scan Tree is the bottom window. Select the Scan Tree; the easiest way is to use the Window menu:



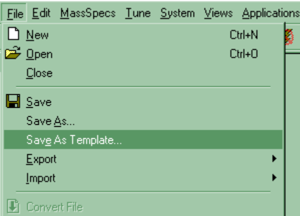
The Scan Tree is Window 1

7. Double-Click on the Global Environment box (Global : RGA) in the scan tree. The Global Environment Editor dialogue box will be displayed.

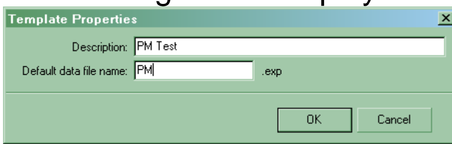
Note: The PM Test file's default mode is RGA, as shown above.

8. Select the **multiplier** in the Environment variables list. Make sure that “Use” checkbox is unchecked to use the current multiplier value from the Instrument. Click OK to close the dialog.
9. Select **mode-change-delay**. Set the **mode-change-delay** to 60000 to wait 1 minute before acquiring data.
10. Click on OK to close the Global environment Editor.

11. From the Menu Bar select the File, Save as Template command.



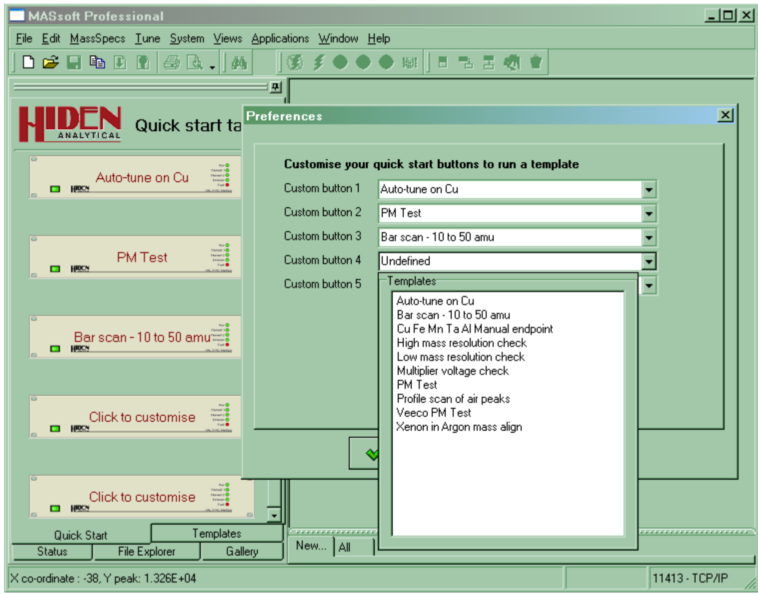
The Template Properties dialog will be displayed.



In the description enter *PM Test*
In the Data File name enter *PM*

12. Click on OK
13. Close the file.

In addition the PM Test template may be assigned to a Quick Start button.



1. Click on an unused button to customise it. Unused buttons have the legend “Click to customise”.
2. The Preferences Quick Start Customisation dialog is displayed.
3. Select from the drop down list of Templates.
4. The template name will be assigned to the button’s legend.

The assignments can also be changed in the Quick Start tab of the Preferences dialogue.

4.3. Running the PM Test

1. Ensure that the EPD is switched on. Both the HAL RC Interface and the SIMS interface must be switched on; these should be switched on before the required vacuum has been achieved to allow the RF head to warm up.

2. Wait until the pressure in the EPD Probe is less than $1x10^{-6}$ Torr.

CAUTION
Operation at pressures higher than $5x10^{-6}$Torr may seriously damage the EPD Probe.

3. Ensure that the plasma or ion beam is off. No wafer etch is needed as the PM test runs in RGA mode.
4. Start MASsoft on the EPD PC.
5. Select MassSpecs, Edit Instrument Environment from the Menu Bar. The Instrument Environment Editor will be displayed.

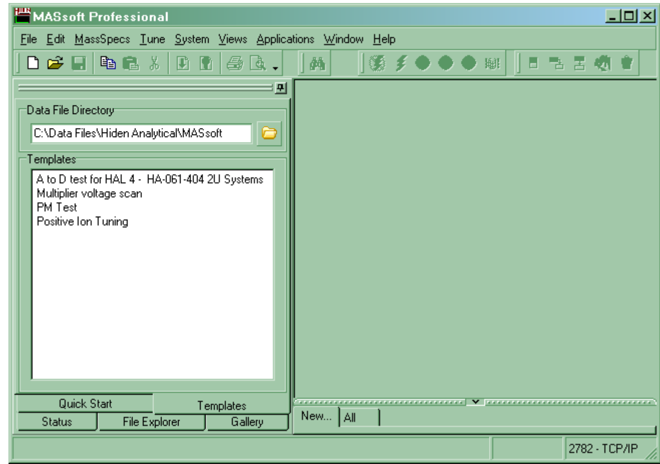
6. Check that the current multiplier voltage has been entered into both the RGA and the SIMS tab. The multiplier voltage in the Shutdown tab should be zero.

   Note: The correct operating voltage of the SEM is the same in RGA and SIMS modes.

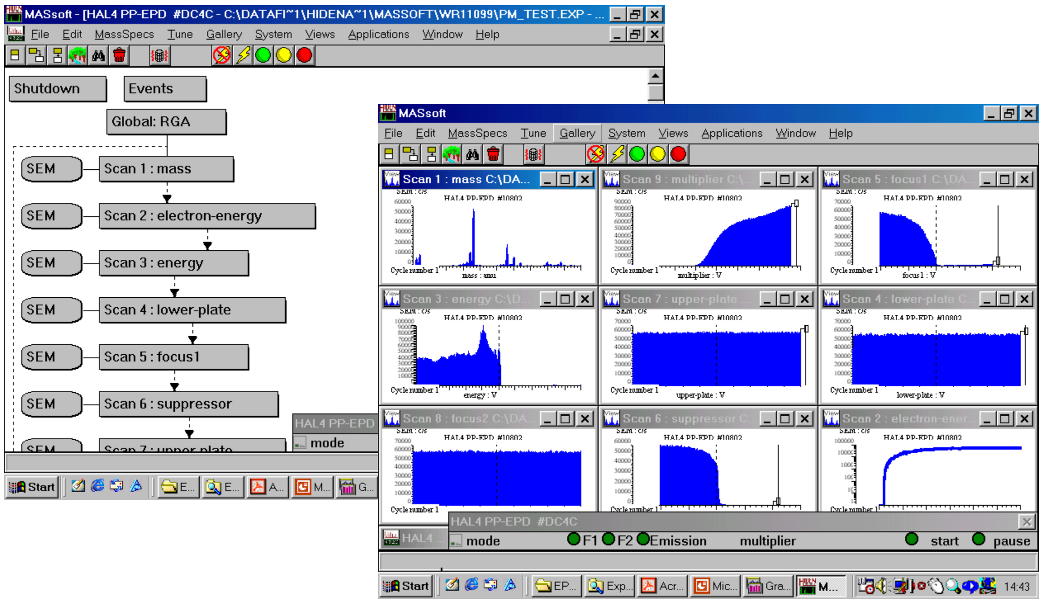
7. Click OK to close the dialogue.

   *Note:The PM Test file must have the "Use" option for the multiplier unchecked in the Global Environment for the Instrument Environment value to be used. See "**Saving the PM Test as a Quick Start Template**".*

8. Select the Template Tab.



9. Double click on PM Test in the Template Tab to run the file. Each run will be saved in a sequentially numbered file PM1.exp, PM2.exp … The files will be saved in Data File Directory specified at the top of the Templates Tab.
10. The MSIU emission LED should be lit in this state. If it is flashing the RGA source Filament has blown.
11. There will be a delay to allow emission to stabilise before scanning starts.
12. The file will acquire three cycles of data, the last of which will be left on the screen and should be examined for problems
13. At the end of the acquisition, the EPD will stop automatically.



A typical view of a pm_test file

One parameter which determines the SEM detector sensitivity is the number of ions it has detected in its lifetime. Each ion carries a charge and the SEM lifetime depends on the total charge it has received. During its lifetime, the knee voltage will increase and the SEM voltage must be increased to accommodate for this.

14. Examine the multiplier scan (X axis label **multiplier : V**)

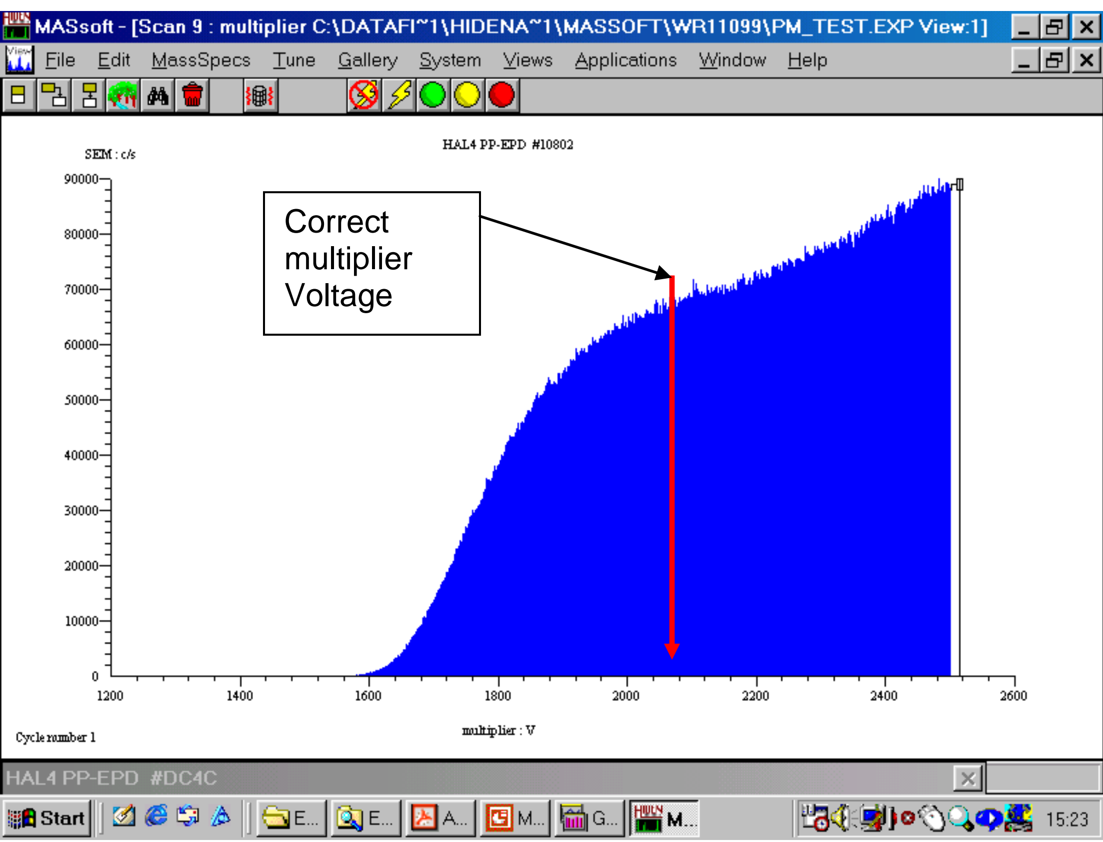
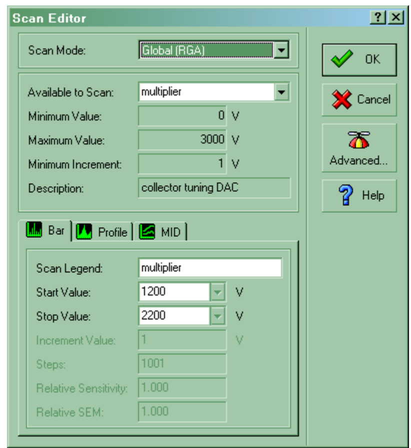


Figure 1. The SEM voltage scan run automatically by the PM_Test.exp file.

15. The correct operating SEM voltage is when the supply voltage is set just above the knee in the profile. Examine the profile created and make note of the correct SEM operating voltage.
16. If the multiplier voltage requires increasing repeat step 5 onwards.
17. As the multiplier voltage increases it may be necessary to increase the upper limit of the multiplier scan. To do this follows steps 18 to 20.
18. Right click on **PM Test** , in the pop-up menu select **edit**.
19. The PM Test file will open for editing.
20. Double-click on multiplier scan in the scan tree. The Scan Editor dialog will be displayed.



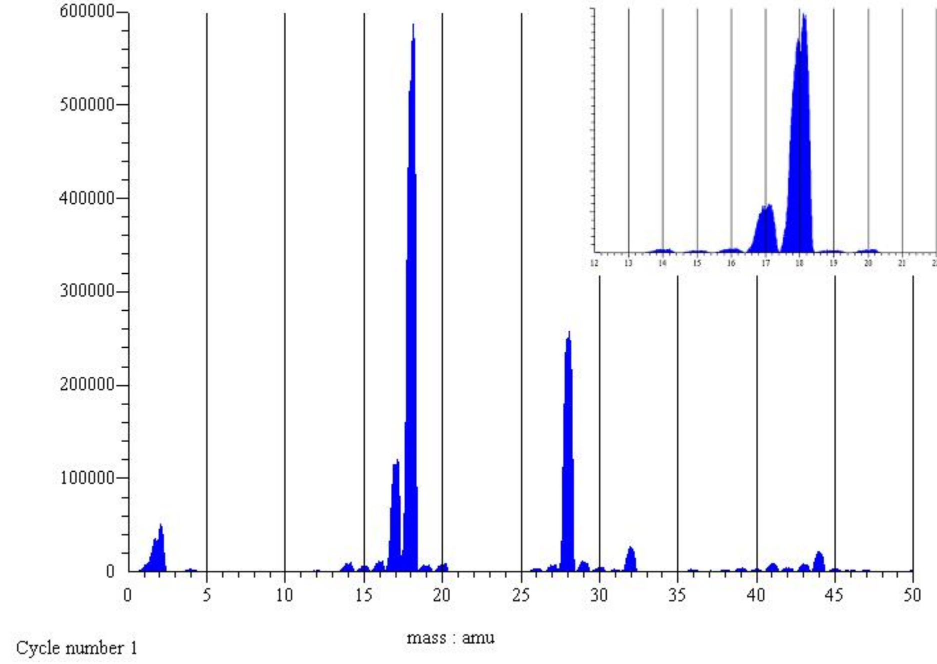
Increase the Stop value to 300V above the expected multiplier voltage, up to a maximum of 3000V. The Start Value may also be increased.

21. Save the file using the **File, Save** command from the Menu Bar.

22. If the required multiplier voltage exceeds 2800V or if the signal is becoming excessively noisy at the new multiplier voltage then the analyzer assembly should be scheduled for exchange.

    After the Analyser has been exchanged the current multiplier voltage will need to be reduced to that required by the new SEM, typically 1900V. The Start Value and Stop Value will also need adjusting downward in the PM Test file's multiplier scan.

23. Note the new multiplier voltage. This should be entered into the Instrument Environment in both RGA mode and SIMS mode. See steps 5 to 7.
24. To check the EPD's mass alignment, examine the position of each peak in the mass spectrum view window (x-axis labeled **mass : amu**). Check the position of each peak relative to the tick mark on the mass (x) axis.



Zoom in on the peaks to see the alignment accurately (inset).

25. To check the resolution of the instrument examine the valley between two adjacent peaks of roughly equal intensity. The valley should nearly come down to the baseline. If possible do this at both the low and high end of the mass scale.

26. If in doubt about the results from these test files please e-mail the entire file set for the run:

The .EXP file with the .SCN file the .ENV file the .ANN file and the .DAT file

to : **service@hiden.co.uk**

27. Retain the files so that they may be used as a reference.

The condition of the EPD can be evaluated from the test results by comparing them with the original file. Use the views acquired in the last cycle (cycle 3) for the comparisons.

Examine the shape of each profile view and compare it with the same view in the reference pmtest file.

5. Tuning the EPD System

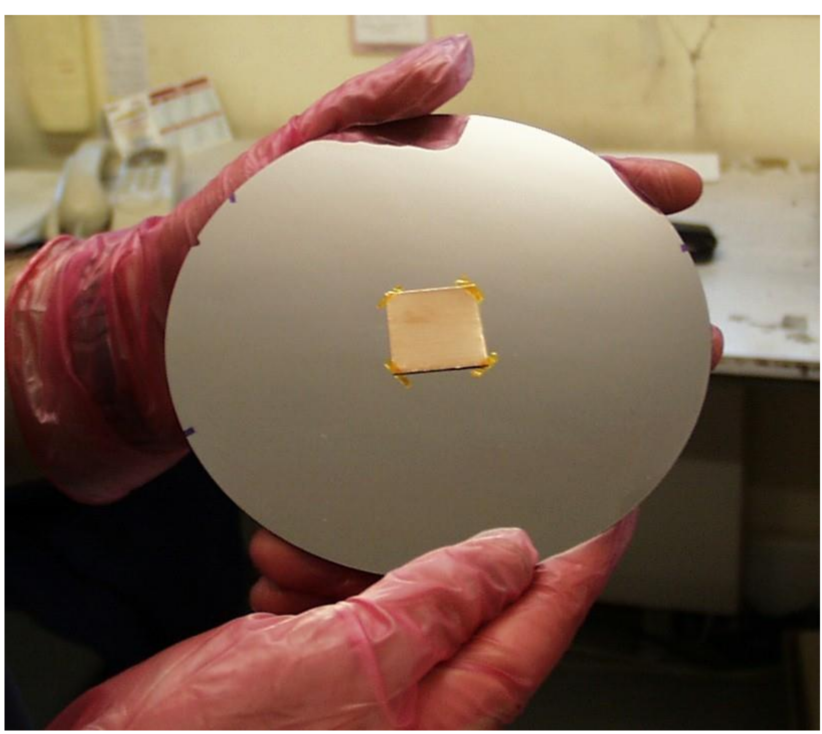
5.1. General

When initially tuning EPD System performance it is essential to run test wafers to optimise the instrument for the System geometry. This will increase the sensitivity of the System and allow endpoints to be detected successfully with a small exposed area on the wafer. When the EPD is shipped from Hiden Analytical Limited, it will hold the operating voltages that were used during testing, and these make a good starting point for the optimisation.

5.2. Tool set-up

For this test, the tool is used to produce the ions that the EPD monitors, and so a test wafer must be loaded in to the system. As the EPD can pick up a signal from anything that the beam hits in the etch chamber (typically aluminium, chromium, titanium, iron, nickel, silicon, and argon from the primary beam), it is recommended that the test wafer be made of a material not found in the wafer clamps, gun grids, chamber walls or shielding.

Usually blank wafer with 2cm^2 piece of copper foil held on by captan tape works very well, as it is not normally used in the manufacture of any item within the chamber, so any copper ions detected are almost certainly being sputtered only from the wafer.



The tuning file will optimise the lens voltages for the Cu and therefore the centre of the wafer.

The lens voltages can then be used by a modified version of the template file which is supplied and a wafer should be completely etched. From this complete etch, the relevent time periods for etch can be obtained to obtain a succesful endpoint.

Optimising at high mass is more difficult than at low mass, and so Tantalum, with a signal appearing at the relatively high mass of 181 amu, is suitable. An ideal test piece would be a small piece (approximately 2 cm2) of Tantalum stuck in the centre of a larger wafer, which also ensures the detector tuning is optimised for the centre of the wafer.

The test piece may be cut from a wafer with Ta deposited on it. The wafer layer on which tuning is carried out must be thick enough to allow time for the endpoint procedure to complete; at least 5000 Å is recommended. At least 30 minutes of etch time should be allowed for tuning.

Note:
For the SIMS scan it is strongly recommended that the wafer is run with NO rotation. It should be positioned at a typical milling angle with wafer rotation disabled and milled using typical primary beam conditions (pressure, power, emission, etc.).

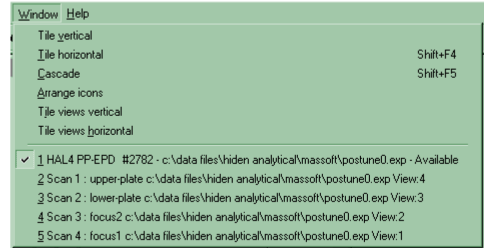
5.3. Saving the AutoTune File as a Quick Start Template

It is a good idea to create an Auto Tune entry in the Templates Tab in MASsoft. This procedure also checks that the multiplier voltage used during the Auto-tune is obtained from the Instrument Environment. It should be used to update auto-tune files created with earlier versions of MASsoft or created on another instrument.

Hiden IMP-EPD systems are shipped with a file called POSTUNE.EXP (POSitive Ion TUNing, pronounced Poz-tune) that was created when the system was tested. This file is configured to tune on mass 27 (aluminium) ; the mass must be changed to 63 to tune on copper or 181 to tune on tantalum.

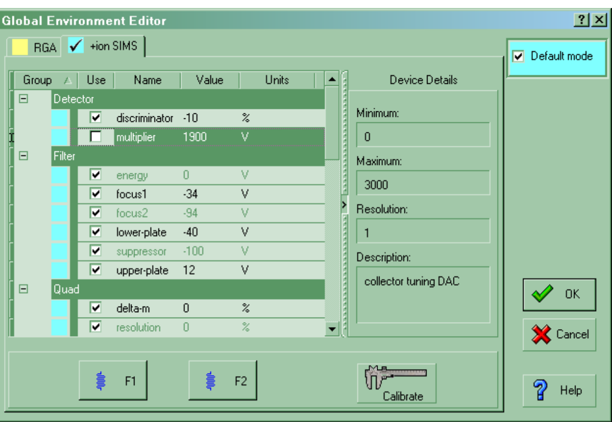
1. Start MASsoft on the EPD PC.
2. Select the Menu Bar File, Open command.
3. Navigate to the \Data Files\Hiden Analytical\MASsoft Pro\WRxxxx folder

4. Open Postune.exp
5. If the file was created on a different instrument then convert the file by using the Convert tool on the tool bar or by selecting File, Convert File from the Menu Bar.
6. If the file is locked unlock the file using the Unlock tool on the tool bar or by select File, Unlock from the Menu Bar.
7. Typically five Windows will be displayed. The Scan Tree is the bottom window. Select the Scan Tree; the easiest way is to use the Window menu:



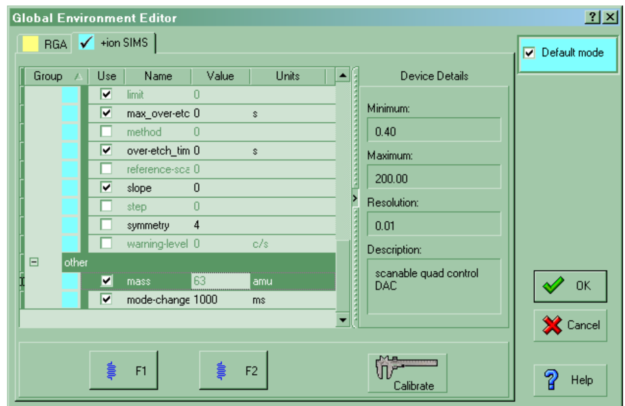
The Scan Tree is Window 1

8. Double-Click on the Global Environment box (Global : +ion SIMS) in the scan tree. The Global Environment Editor dialogue box will be displayed.



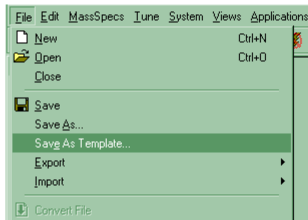
Note: The Autotune file's default mode is +ion SIMS, as shown above.

9. Select the **multiplier** in the Environment variables list. **multiplier** is in the **Detector** group. Make sure that "Use" checkbox is unchecked to use the current multiplier value from the Instrument. Click OK to close the dialog.
10. Select the **mass** in the Environment variables list. **mass** is in the **other** group.

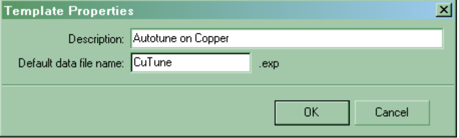


Enter the mass to match the wafer being tuned. Cu = 63. Ta = 181

11. Click on OK to close the dialogue.
12. From the Menu Bar select the File, Save as Template command.



The Template Properties dialog will be displayed.

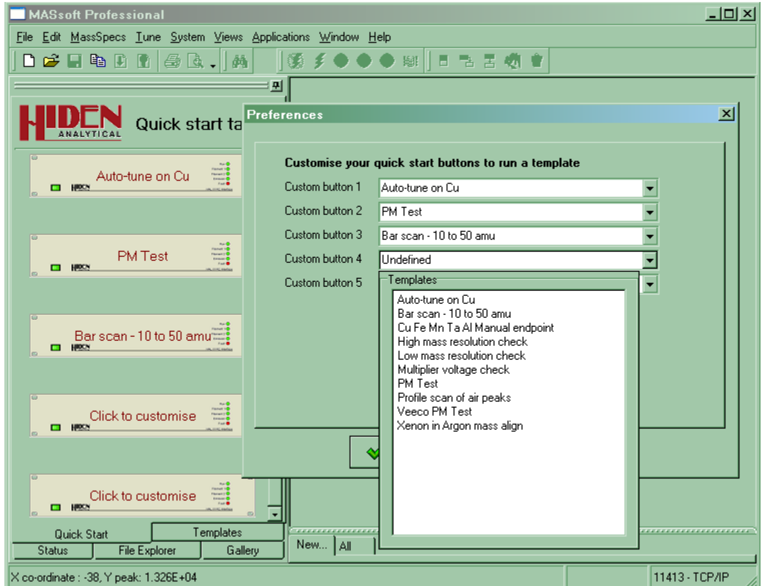


Enter the description and data file name. For instance when tuning on copper:
In the description enter *Autotune on Copper*
In the Data File name enter *CuTune*

The description will appear in the Templates Tab and on the Quick Start button if the template is assigned to a button.
The Default data file name will be used to generate sequentially numbered files e.g. CuTune1.exp CuTune2.exp …

13. Click on OK. The file will be saved in the Template folder. The original Postune file will remain unchanged.
14. Close the file.

In addition the Autotune template may be assigned to a Quick Start button.



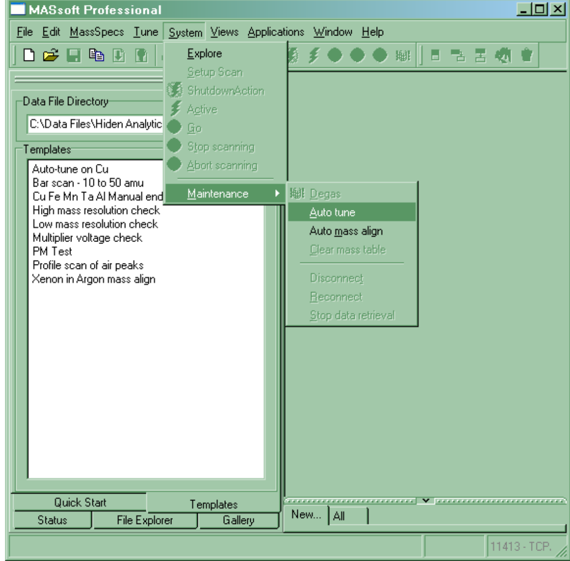
1. Click on an unused button to customise it. Unused buttons have the legend “Click to customise”.
2. The Preferences Quick Start Customisation dialog is displayed.
3. Select from the drop down list of Templates.
4. The template name will be assigned to the button’s legend.

The assignments can also be changed in the Quick Start tab of the Preferences dialogue.

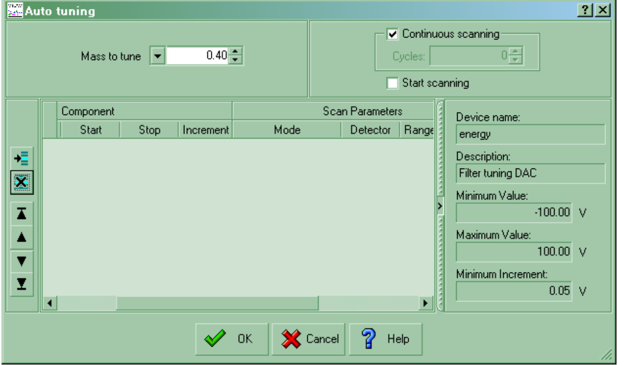
5.4. Creating an AutoTune File

Alternatively the Autotune file may be created from scratch.

1. From the Menu bar select System, Maintenance, AutoTune

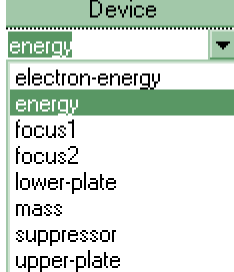


2. The Auto tuning dialog is displayed.

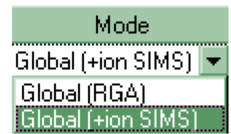


The Auto tuning dialog remembers the last values that you used. If necessary use the button to delete unwanted rows.

3. Enter the mass of the ion to be tuned in to “Mass to tune”
4. The first lens to be tuned should be **energy**. Use the button to create a new row in the table.
5. In the Device column select **energy** from the drop down list



6. Ensure that the Mode of the scan is +ion SIMS.

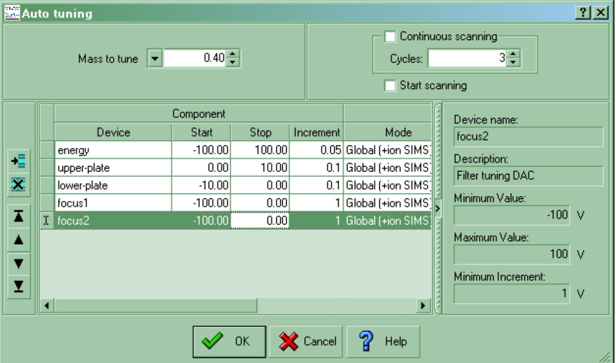


The remaining scans will default to the same mode as the first scan.

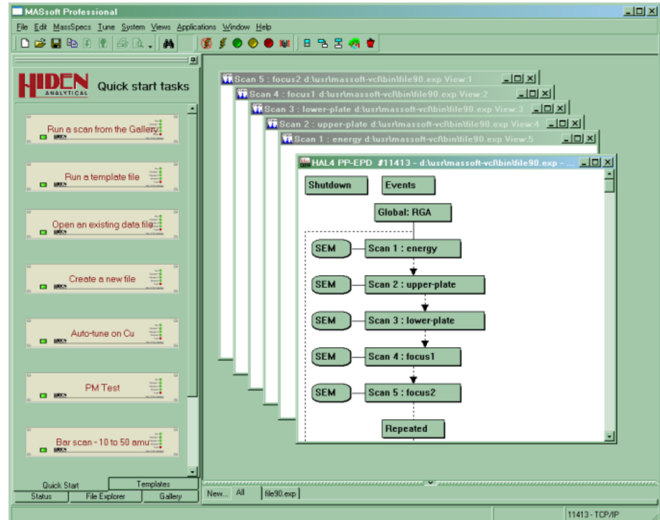
7. For **energy** set the start value to 0 V and the stop value to 10 V with and increment of 0.05 V.
8. Use the button to create the next row in the table. The mode should default to +ion SIMS.
9. Create rows for each of the devices in this table and enter the Start, Stop and Increment values as shown.

Device	Start	Stop	Increment
energy	0 V	10 V	0.05V
upper-plate	0 V	10 V	0.1 V
lower-plate	-10 V	0 V	0.1V
focus1	-100 V	0 V	1 V
focus2	-100 V	0 V	1 V

10. Un-check the continuous scanning check-box, and set the number of cycles to 3.
11. Un-check the Start scanning check-box Start scanning.
12. The completed Autotune table should resemble this:



13. Click OK to close the dialogue.
14. The Autotune file will be created with a view for each scan.



15. Double-Click on the Global Environment box (Global : +ion SIMS) in the scan tree. The Global Environment Editor dialogue box will be displayed.

Note: The Autotune file's default mode is +ion SIMS, as shown above.

Select the **multiplier** in the Environment variables list. **multiplier** is in the **Detector** group. Make sure that "Use" checkbox is unchecked to use the current multiplier value from the Instrument Environment.

The lenses in the Filter group should have their "Use" check box checked to define the initial values for the lenses. The devices should be set to the following initial values:

Device	Value
Energy	0 V
focus1	-50 V
focus2	-50 V
lower-plate	-2.5V
suppressor	-100V
upper-plate	+2.5V

If the “Use” checkboxes of these devices are left unchecked autotuning will use the values from the Instrument Environment as its initial conditions.

.

16. Save the file using the File, Save as Template command from the Menu Bar. (see “***Saving the AutoTune File as a Quick Start Template”)***.

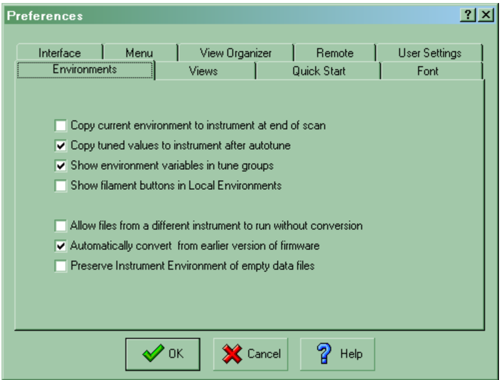
5.5. Running the AutoTune file

Optimising the system for EPD operation is not difficult as there is a **AutoTune** procedure in MASsoft which does the tuning automatically. For an explanation of how AutoTune works, see Manual number HA-085-004, “MASsoft User Manual”.

For the **AutoTune** procedure it is strongly recommended that the wafer is run with NO rotation. It should be positioned at a typical milling angle with wafer rotation disabled and milled using typical primary beam conditions (pressure, power, emission, etc.). The undulation seen in the signal from the wafer when it is rotating can confuse the **AutoTune** procedure and cause it to optimise on spurious electrode settings.

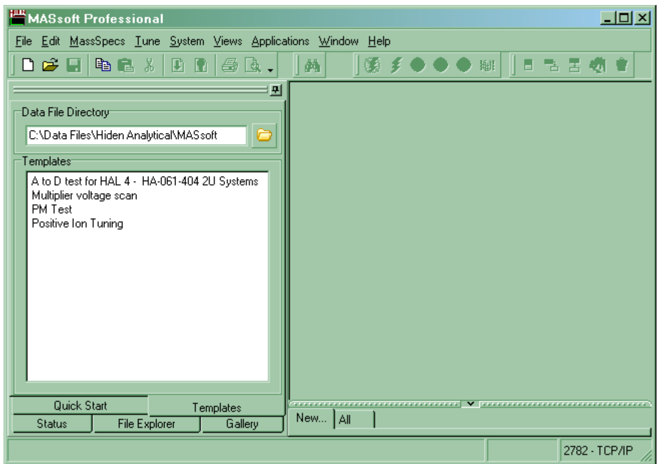
After autotuning the tuned values will be saved to a .tun file and to the Instrument Environment.

To ensure that the tuned values are saved to the Instrument Environment please check that “Copy tuned values to Instrument Environment after autotune” is selected in the Environment Tab of the Preferences dialog.



The “Copy current environment to instrument at end of scan” option should not be selected. If this option is selected it may result in values in the Instrument Environment being over-written by values from old files.

1. Select the Template Tab.



2. Double click on required autotune file in the Template Tab to run the file. Each run will be saved in a sequentially numbered file e.g. CuTune1.exp, CuTune2.exp … The files will be saved in Data File Directory specified at the top of the Templates Tab.

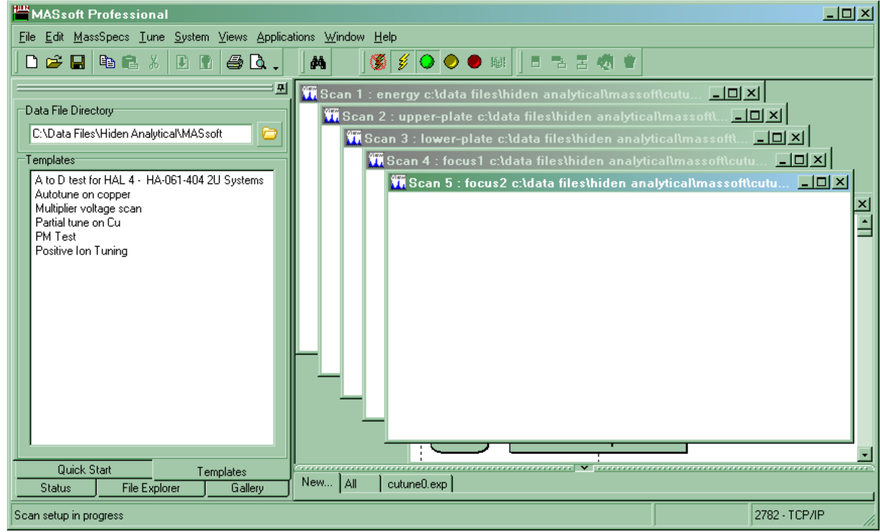


Figure 6

A screen similar to Figure 6 will be displayed.

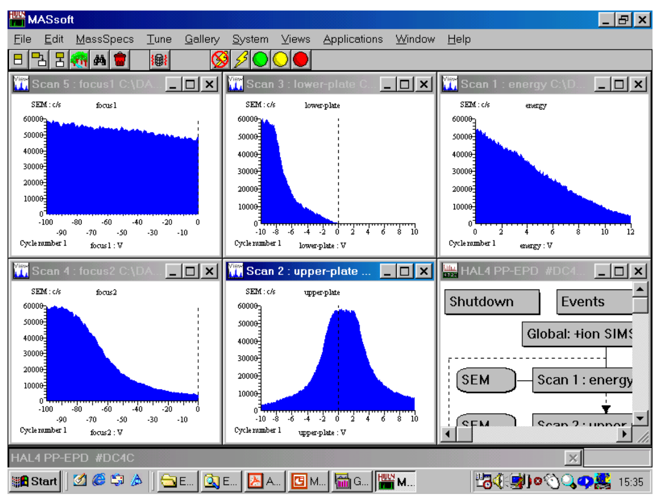
3. Select the menu bar **Window**, **Tile vertical** command.

All the Views are displayed

The EPD Probe electrode voltages will be scanned sequentially, beginning with the electrodes at the front of the EPD.

Three cycles will be acquired, each

cycle further refining the voltages on the electrodes.



.

At the end of acquisition a dialogue box will appear asking if the file is to be saved as a ***.tun** file.

4. Select the **Yes** push-button

.This closes down the scan and saves the tune file. The tune file may later be imported d in to a Instrument, Global or Local Environment.

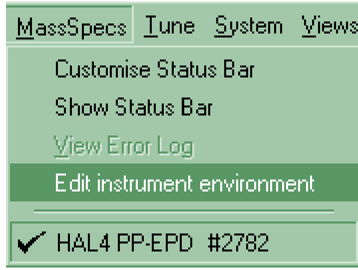
The EPD will retain the optimised values it found in the Instrument Environment.

Note The "Copy tuned values to Instrument Environment after autotune" in the Environment Tab of the Preferences dialog must be set.

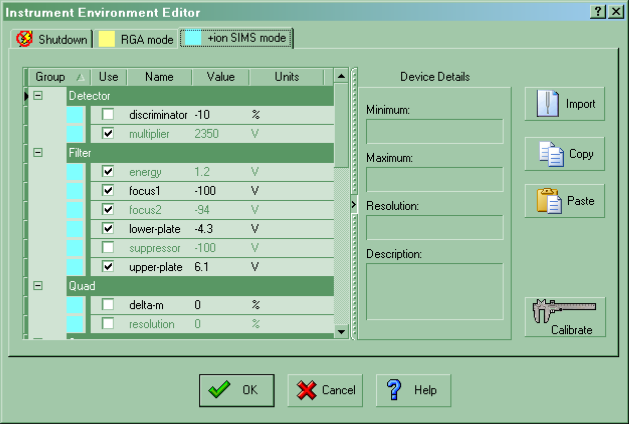
5. Switch-off the ion beam.
6. Remove the test wafer.

To view the new settings:

1. Select the Menu Bar MassSpecs, Edit instrument environment command;



2. The Instrument Environment Editor dialog will be displayed.



3. Select the +ion SIMS tab. The tuned values will be shown in the Filter group. Their “Use” checkbox will be checked.

   The values of **Energy**, **Upper Plate**, **Lower Plate**, **Focus 1** and **Focus 2** are the values which produced optimum signal levels.

4. Select the **OK** push-button. The **Instrument Environment Editor** dialogue box is closed.

6. Endpoint Methods

6.1. Methods

The **method** endpoint variable controls the way endpoints are found.

There are two basic ways of finding endpoint:
Looking for the rising edge of a peak and finding endpoint when the signal rises above a reference level.
Looking for the falling edge of the peak and finding endpoint when the signal drops by a specified amount or below a reference level.

To these basic ways the following may be added.

1. Use of a separate reference peak to measure a reference level
2. Layer counting to end on the second (or later) occurrence of a layer.
3. Methods that are less susceptible to variation in the signal due to rotation.

The material to endpoint on is specified by the endpoint-scan variable, this specifies a scan in the Scan Tree; the mass specified in this scan determines the ion measured.

In addition a **reference-scan** may be specified.

6.2. Rising edge methods

Method 1/

Method 1 is the simplest rising edge method. Endpoint is found when the signal from the endpoint-scan exceeds the **limit** variable and the gradient exceeds the **slope** variable.

Endpoint is found when the current level – minimum level is greater than the limit value.

The minimum level is the lowest signal level of the endpoint-scan occurring after the **initial-delay** but before the peak.

The disadvantage of this method is that endpoint is set by an absolute level; as the sensitivity of the instrument decreases as the multiplier ages the signal will decrease causing endpoint to be found later, or not at all. It will also be susceptible to changes in peak height due to changes in etch rate or other conditions. Different levels will have to be used for unmasked qualification wafers and masked production wafers.

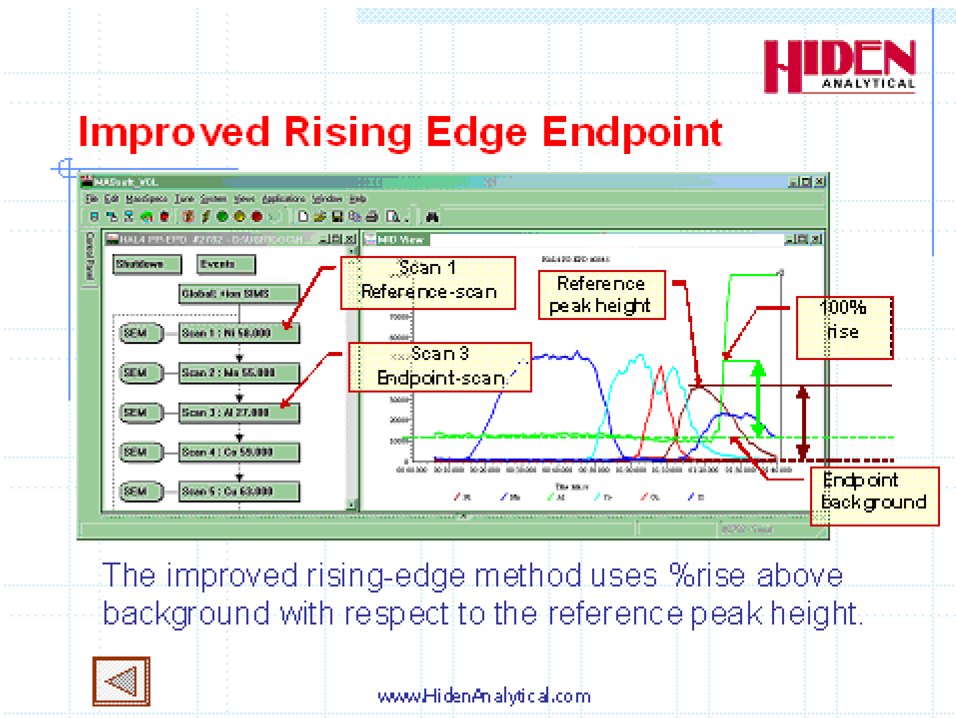
Method 2/

Method 2 is identical to method 1.

Method 3/

Method 3, rising edge relative to a reference, overcomes the disadvantages of method 1. Endpoint is found when the signal from the endpoint-scan exceeds a limit value calculated as a percentage of the height of a reference peak specified by the **reference-scan** variable.

Method 3 uses the **%fall** variable to hold the % rise.



The reference peak must precede the endpoint peak. The reference level is calculated as the difference between the lowest signal before the peak and the highest signal during the peak; the value may be revised upward if a later reference peak is encountered.

The **%fall** variable is applied to the reference level to calculate the endpoint level using the expression:

Endpoint level = Reference Level * %fall / 100

Endpoint is found when the current level – minimum level is greater than the endpoint level.

Note that in methods 3 , 13 and 23 the **%fall** is used as a straight percentage of the reference level. Values greater than 100% may be used to set the endpoint level to a value higher than the reference peak.

6.3. Falling edge methods

Before the falling edge of a peak can be found the rising edge must be found, that is the current signal must exceed the **limit** variable and the gradient must exceed the **slope** variable.

Method 5/

Method 5 is the simplest falling edge method. Endpoint is found on the falling edge of the peak when the signal from the endpoint-scan drops by the percentage specified in the **%fall** variable from its maximum value.

If no reference scan is specified the maximum level is calculated from the endpoint-scan as the difference between the lowest signal before the peak (the minimum level) and the highest signal during the peak;

The **%fall** variable is applied to the maximum level to calculate the endpoint level using the expression:

Endpoint level = Maximum Level * (100 - %fall) / 100

Endpoint is found when the current level – minimum level is less than the endpoint level.

Thus for a 25% fall the signal has to fall below 75% of the maximum level.

Method 5 may also be used with a reference peak. In this case the endpoint level will be calculated from the reference level as defined in method 3.

Endpoint level = Reference Level * (100 - %fall) / 100

Note: Endpoint is defined as a percentage fall from the height of the reference peak.

Method 4/

Method 4 is similar to method 5, but will also find endpoint if the current level – minimum level falls below the limit.

You might use method 4 if the %fall required is large, say 90%. If the peak does not reach this it will still endpoint if and when it falls below limit.

6.4. Layer Counting

It is not uncommon for a wafer stack to have two or more layers of a material. Layer counting allows you to specify which layer to endpoint on. Methods 11 – 15 enable layer counting. The number of layers is specified by the endpoint-layer variable.

Methods 11-15/

Each method, 1 -5, has an equivalent layer counting method, 11 – 15.

A layer is counted when it falls back below the %fall or limit value, for exact details for each method see the Method Summary table.

Methods 21-25/

A problem arises when using reference peaks if one or more layers precede the reference peak. In this case the reference level will be zero and the criterion of falling below the reference level will never be met. In this situation methods 21 – 25 should be used. These methods determine the end of the layer by comparing the current level with the limit variable instead.

Another common situation is where the endpoint material is used for both the first and last layer of the stack (e.g. Ta caps). In this case the initial-delay should be used to skip the first layer instead of using layer counting.

The reason for this is because the signal for the first layer begins high as soon as the shutter opens. No minimum level can be evaluated. The signal begins high and may not meet the slope criterion for a rising edge so the start of the peak is not detected.

If the scan ends without finding the expected number of layers this is recorded in the log;

```
Template METHODS.EXP v1.    17:26:20 27/01/2006
File = "d:\file name          17:26:22 27/01/2006
Step  3 started at:  17:26:23 27/01/2006
Cleanup started 17:27:16 27/01/2006
 56.348s - Run aborted  . 17:27:17 27/01/2006
Limit not reached. 17:27:18 27/01/2006
 1 layer(s) not found. 17:27:19 27/01/2006
Endpoint peak less than warning level.  17:27:20 27/01/2006
 PM Check due. 17:27:21 27/01/2006
Slope    9 , Min  -0.0039 , Reference pk ht 4.80000E+1 , Level of %fall above Min. 2.40000E+1 17:27:22 27/01/2006
```

In this case this occurred because the second peak was too small.

6.5. Endpointing in the Presence of Rotational Variation.

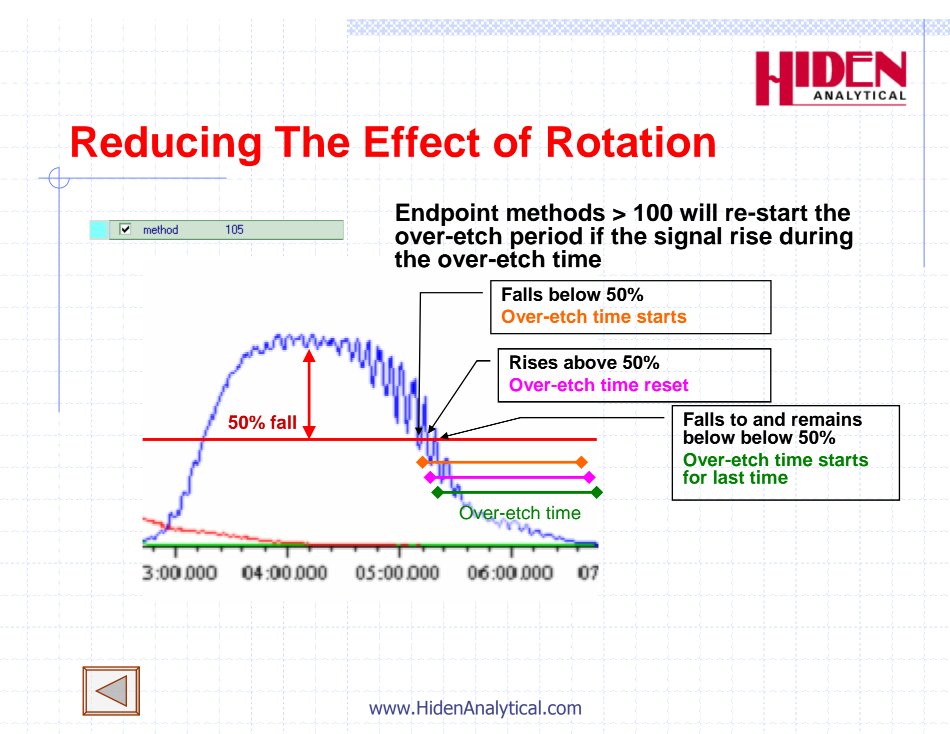
Rotation of the wafer may cause the signal to vary as different areas of the mask enter the cone of acceptance; variation is also caused by rotating source magnets. Rotational variation can be minimised by ensuring that the probe is correctly aligned and that the upper and lower plate voltages are tuned to the centre of the wafer.

Use of the **RPM** and **symmetry** variables can also reduce rotational variation.

However it may not me possible to remove the effects of rotation completely and this may affect the determination of the endpoint.

Method 105, 115 and 125/

Methods 105, 115 and 125 prevent endpoint being found too soon on a falling edge by re-setting the endpoint if the signal rises back above the endpoint level during the over-etch period. The over-etch period is re-started when the signal falls below the endpoint level again; for this method to work correctly the over-etch time must be longer than the rotational period.



6.6. The Chart Marker.

A chart marker may be added to your scan. The chart marker will indicate the point at which endpoint was detected.

The chart marker will also indicate the initial delay period, layers when layer counting and the over-etch period; the chart marker does this by using different levels.

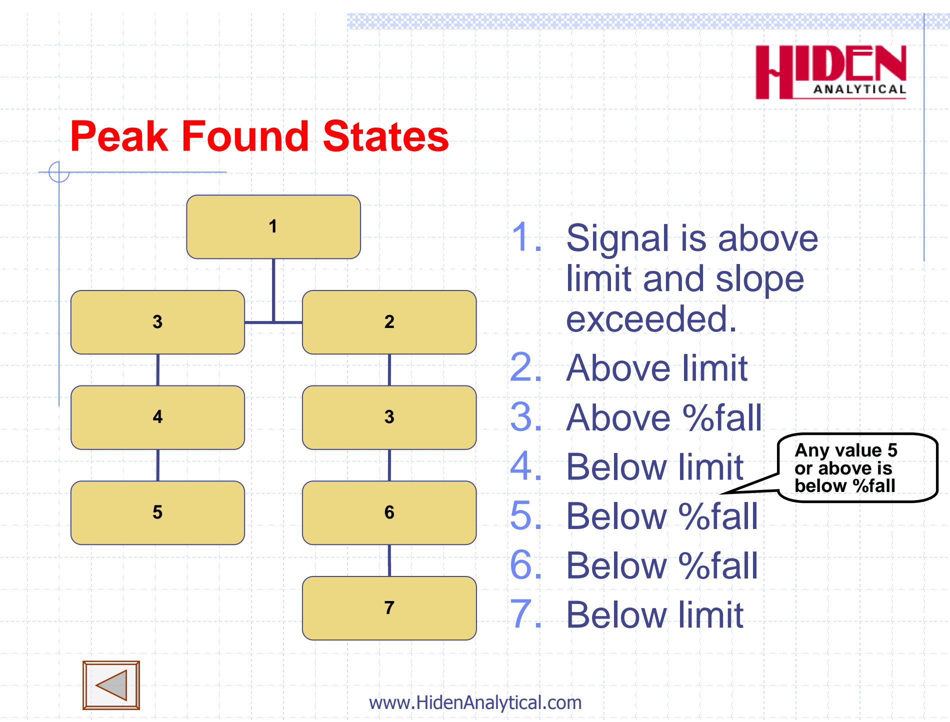
During the initial delay the chart mark has the value 10.
At the end of the initial delay the chart mark goes to zero.
When the endpoint-scan goes above the slope and limit the chart mark goes to the value 1.
This will change to 2 or 3 immediately. Values between 2 and 7 indicate the progress of peak detection until endpoint is found.

When endpoint is found the chart mark goes to the value 15 for the duration of the over-etch period. At the end of the over-etch period the chart mark goes to the value 20, until the scan is stopped by the PM

Chart Mark Value	Meaning
10	Initial delay
0	No peak

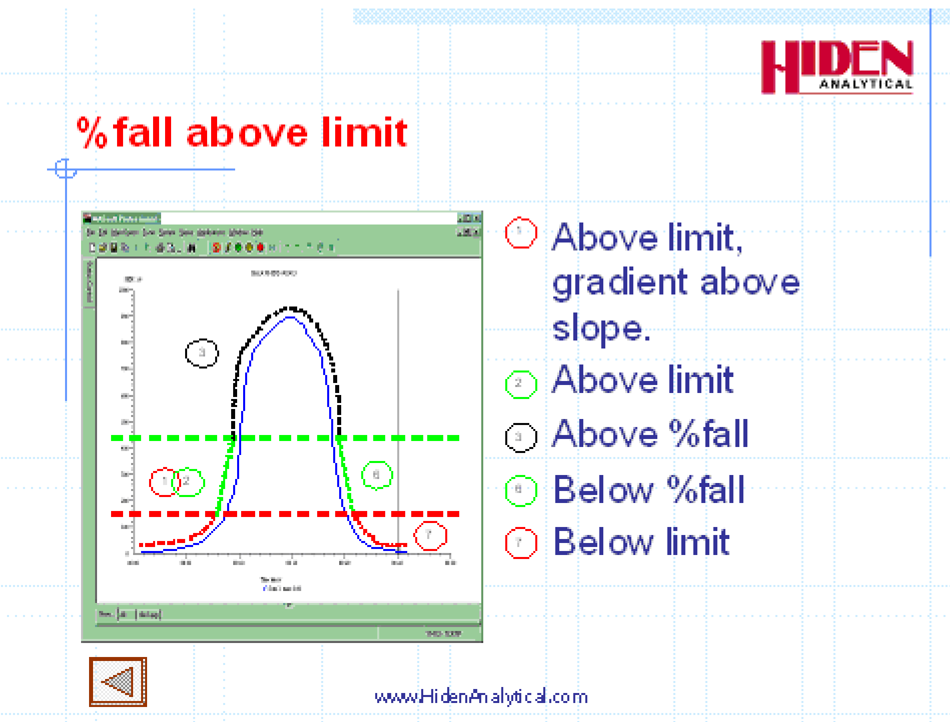
1	Signal is above limit and slope exceeded.
2	Above limit
3	Above %fall and above limit.
4	Below limit, above %fall
5	Below %fall and limit
6	Below %fall, above limit
7	Below limit and %fall
15	Endpoint found – overetch period started.
20	Endpoint found – overetch period complete.

The values between 1 and 7 are best understood by reference to this sequence diagram. The branch taken depends on whether the signal level equivalent to the %fall value is above or below the limit. If the %fall level is less than the limit then the sequence will go immediately to 3 as soon as the condition for 1 is met. It will then follow the sequence 3 - 4 - 5 . However usually the level for %fall will be above the limit, so the normal sequence is 2 – 3 – 6 – 7.



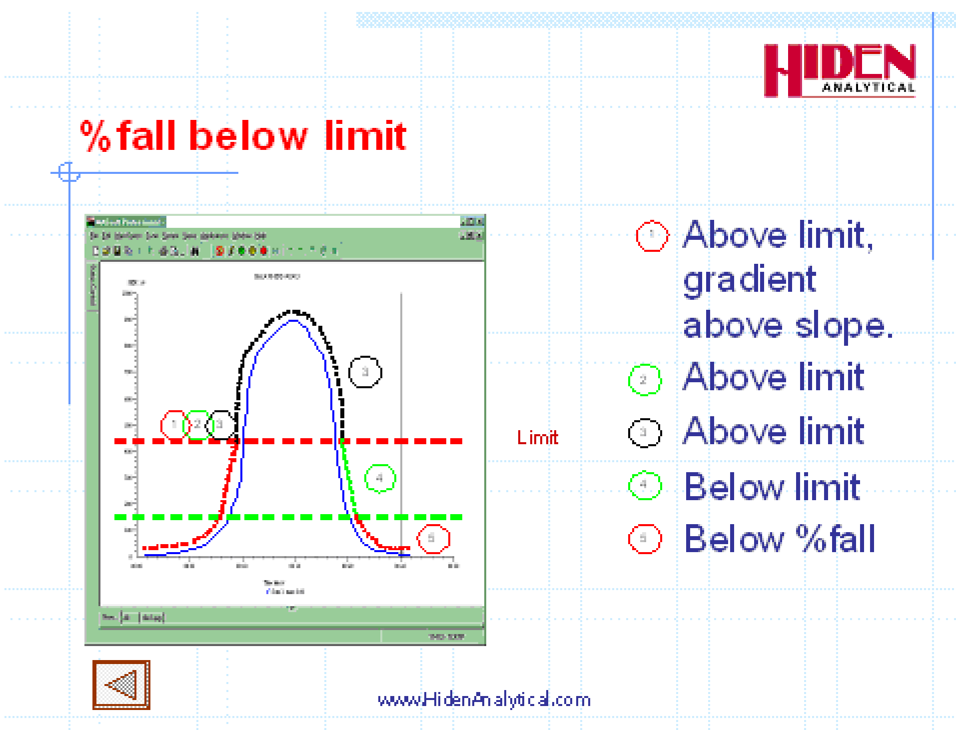
These values also correspond to the endpoint methods, because endpoint is found when the value is >= the basic method number. For instance method 4 (or 14, 24, 104 etc.) will end when the signal drops below either the limit or the %fall level, whichever comes first. Method 5 ends when the signal drops below the %fall. Methods 6 & 7 would require the %fall level to be above the limit.

Normal sequence if the level equivalent to %fall (geeen line) is above the limit (red line) :



1 & 2 Above limit
3 Above %fall
6 Below %fall
7 Below %fall and limit

Sequence if level equivalent to %fall (green line) is below the limit (red line):



1,2 Above limit
3 Above %fall
4 Below limit, Above %fall
5 Below limit and below %fall

6.6.1. Method Summary

Standard Methods	Layer counting Methods	Layer counting (1st layer precedes Reference peak)	Rotation proof Methods
1 Rising edge	11 Rising edge*	21 Rising edge#	
2	12	22	
3 Rise relative to reference	13 Rise relative to reference +	23 Rise relative to reference #	
4 Below %fall or limit	14 Below %fall or limit *	24 Below %fall or limit #	104 114 124
5 Below %fall	15 Below %fall+	25 Below %fall#	105 115 125

Method used to determine end of layer when layer counting:
* Less than % fall or limit
+ Less than %fall
# less than limit

Method 1 – Rising edge

Endpoint found as soon a signal of endpoint-scan exceeds limit.

Method 2

Effectively identical to method 1

Method 3 – Rising edge (Above %fall)

With no reference peak this behaves the same as method 1. (until the maximum is reached the signal is bound to be above %fall)

If a reference-scan is specified endpoint is found when the signal from the endpoint-scan exceeds %fall percent of the signal of the reference-scan

Method 4 – Falling edge (Below limit or %fall)

Endpoint found when the signal from the endpoint-scan is less than limit or the if the endpoint-scan signal has fallen by %fall percent from its maximum.

You might use method 4 if the %fall required is large, say 90%. If the peak does not reach this it will still endpoint if and when it falls below limit.

Method 5 – below %fall

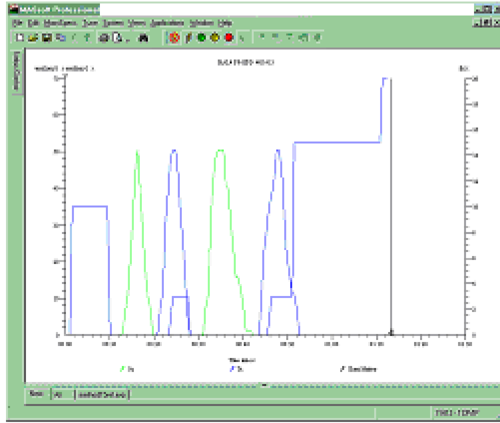
Endpoint not found until the signal from the endpoint-scan has fallen by %fall percent from its maximum, even if this is below limit.

Method 5 with reference

Endpoint not found until the signal from the endpoint-scan has fallen below a level equal to %fall percent from the maximum of the signal specified by the reference-scan, even if this is below limit

Method 15 with reference and layer counting

Method 15 uses the endpoint-layer variable to specify the layer of a material to endpoint on.

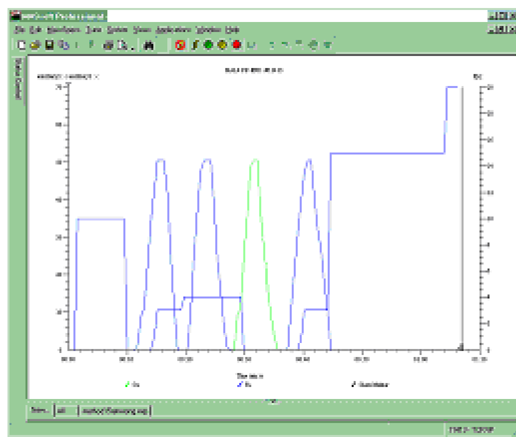


The green layer is measured by the reference-scan.

The layer counting is counting layers of the blue material so the green layers are not counted. endpoint-layer is set to 2 so the endpoint is found on the second blue peak

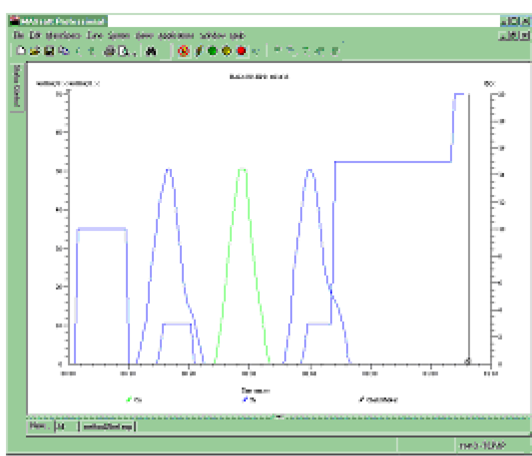
Note that the reference-scan layer must precede the first endpoint-scan layer for the layers to be counted correctly using method 15.

In this example the chart marker shows that end of the first two blue peaks was not found until the green reference peak starts. As a result the two blue layers were counted as a single layer.



Using method 15 you can not end the first layer using %fall if first endpoint layer is before the reference peak; in this case you must use method 25 which finds the end of the layer using the limit value.

Method 15 with reference and layer counting



In the above example using method 25 the chart mark shows that the end of the first blue layer is found when the signal drops below the limit value.

6.6.2. Error Reporting

Logs error if run ended during initial delay:

Template METHODS.EXP v1.   17:23:09 27/01/2006
File = "d:\file name   17:23:10 27/01/2006
Step 3 started at: 17:23:11 27/01/2006
Cleanup started 17:23:20 27/01/2006
12.778s - Run aborted . 17:23:21 27/01/2006
Endpoint not found. 17:23:22 27/01/2006
Ended during initial-delay. 17:23:24 27/01/2006
Slope   0 , Min   922337203685477.5807 , Reference pk ht 0.00000E+0 , Level of %fall above Min. 0.00000E+0 17:23:25 27/01/2

Logs error if endpoint peak does not reach limit:

Template METHODS.EXP v1.   17:26:20 27/01/2006
File = "d:\ file name   17:26:22 27/01/2006
Step 3 started at: 17:26:23 27/01/2006
Cleanup started 17:27:16 27/01/2006
56.348s - Run aborted . 17:27:17 27/01/2006
Limit not reached. 17:27:18 27/01/2006
1 layer(s) not found. 17:27:19 27/01/2006
Endpoint peak less than warning level. 17:27:20 27/01/2006
PM Check due. 17:27:21 27/01/2006
Slope   9 , Min -0.0039 , Reference pk ht 4.80000E+1 , Level of %fall above Min. 2.40000E+1 17:27:22 27/01/2006

Logs error if run is ended by PM during overetch period:

Template METHODS.EXP v1.   17:33:53 27/01/2006
File = "d:\ file name   17:33:54 27/01/2006
Step 3 started at: 17:33:55 27/01/2006
Cleanup started 17:34:59 27/01/2006
68.428s - Run aborted . 17:35:00 27/01/2006
Ended during overetch. 17:35:01 27/01/2006
Endpoint found at 48.651 17:35:02 27/01/2006
19.785 s overetch. 17:35:03 27/01/2006
Slope   22 , Min -0.0039 , Reference pk ht 2.40000E+1 , Level of %fall above Min. 1.20000E+1 17:35:04 27/01/2006

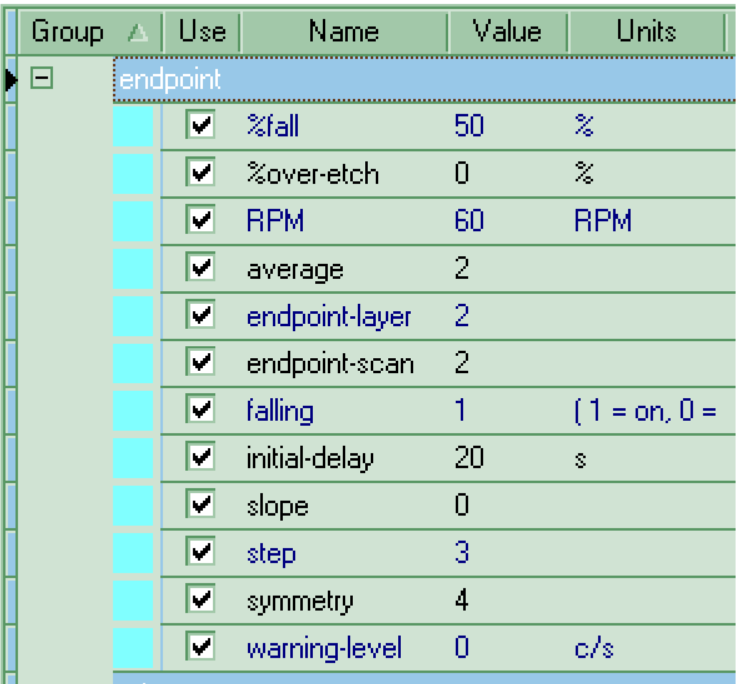
7. IMP EPD Endpoint Variables

End point detection is performed by the Event Sequence.
The Event Sequence is copied from the original Template file – you should not need to edit the sequence.
The sequence is controlled by variables in the Global Environment.

This section covers the endpoint variables in the Global Environment and how to determine their correct values.

The correct values will be determined from data acquired by a manual etch of the wafer.

Endpoint variables are found in the endpoint group in the Global Environment.



Group	Use	Name	Value	Units
endpoint				
	☑	%fall	50	%
	☑	%over-etch	0	%
	☑	RPM	60	RPM
	☑	average	2	
	☑	endpoint-layer	2	
	☑	endpoint-scan	2	
	☑	falling	1	(1 = on, 0 =
	☑	initial-delay	20	s
	☑	slope	0	
	☑	step	3	
	☑	symmetry	4	
	☑	warning-level	0	c/s

Values for endpoint variables should be set in +ion SIMS mode only, values for other modes and Shutdown are not used.

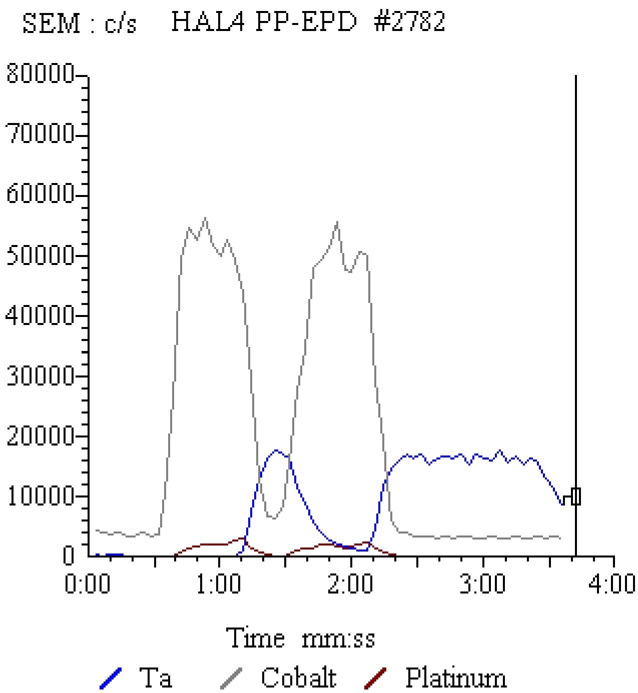
Do not set endpoint values in Local Environments. All the values in the endpoint group in a Local Environment must have their “Use” checkbox un-checked.

7.1. Determining the Endpoint variables

To generate the Endpoint variables, run a template file manually, (see Section 7.6), on a test wafer etch. Note that if you run an unmasked qualification wafer then the values for the limit, slope and warning-level variables will have to be adjusted to those expected for a masked production wafer.

Open the test wafer etch file using the Menu Bar **File,**
Open command. Use MASsoft's data manipulation facilities to examine the data and
derive values as follows:

7.2. Method Variables



- Examine the data to determine the desired endpoint. In the above scan it might be at the second Co / Ta interface.
- Decide whether you want to use a rising or falling edge as your endpoint. In the above example this would be the falling edge of Co or the rising edge of Ta. The advantage of the falling edge is that it is relative to the maximum peak height so does not change as the system sensitivity changes.
- Choose your basic endpoint method, 1 for rising edge, 5 for falling edge.
- With reference to the scan tree, the endpoint-scan will depend on the layer you are endpointing on. In the above example it would be scan 2 if ending on the rising edge of Ta or scan 3 if ending on the falling edge of Co (Scan 1 is used for the chart mark)

- If using the rising edge consider using a reference scan so that the endpoint does not vary with system sensitivity. In the above example Co or Pt could be the reference scan. Using the larger signal would mean that you would end on 15% of the Co peak (55,000 c/s) to stop half way up the Ta peak (17,000 c/s).
- If there is more than one layer of the endpoint material then use the endpoint-layer to specify which layer to end on. In the above example the endpoint-layer should be set to 2 to end on the second Co or Ta layer. If ending on the rising edge of Pt and using Co as the reference peak then use method 11, because the first Pt layer is preceded by a Co layer and so can use the same end criteria as the endpoint. If the first Co layer were absent you would have to use method 21 so that the end of the first peak was determined by the **limit** variable

method

Set this to the desired endpoint method. See section

endpoint-scan

Set this to the scan number of the scan that measures the endpoint material.

reference-scan

Set **reference-scan** to 0 if no reference peak is required.
Set this to the scan number of the scan that measures the reference peak

endpoint-layer

Used with methods 11-15 and 21-25. Specifies which layer to endpoint on when there is more than one layer of the material specified by the endpoint-scan.

Note. Only layers of the material specified by the endpoint-scan are counted.

Note. Use the initial-delay to skip the layer if the material specified by the endpoint-scan is the first layer in the stack.

falling

Retained to support older template files.
Only used by method 0.
For a rising edge endpoint use method 0 with falling set to 0, this is equivalent to method 1.
For a falling edge endpoint use method 0 with falling set to 1, this is equivalent to method 5.

7.3. Rising Edge Variables

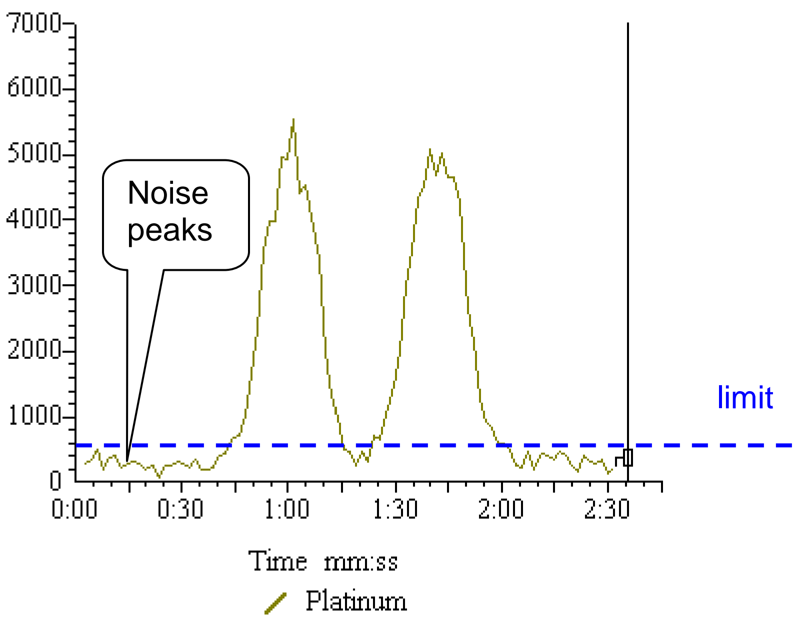
The rising edge variables are used to detect endpoint on a rising edge endpoint and to detect the beginning of a peak on a falling edge endpoint.

Endpoint will not be found if the peak does not meet these endpoint criteria.

initial-delay

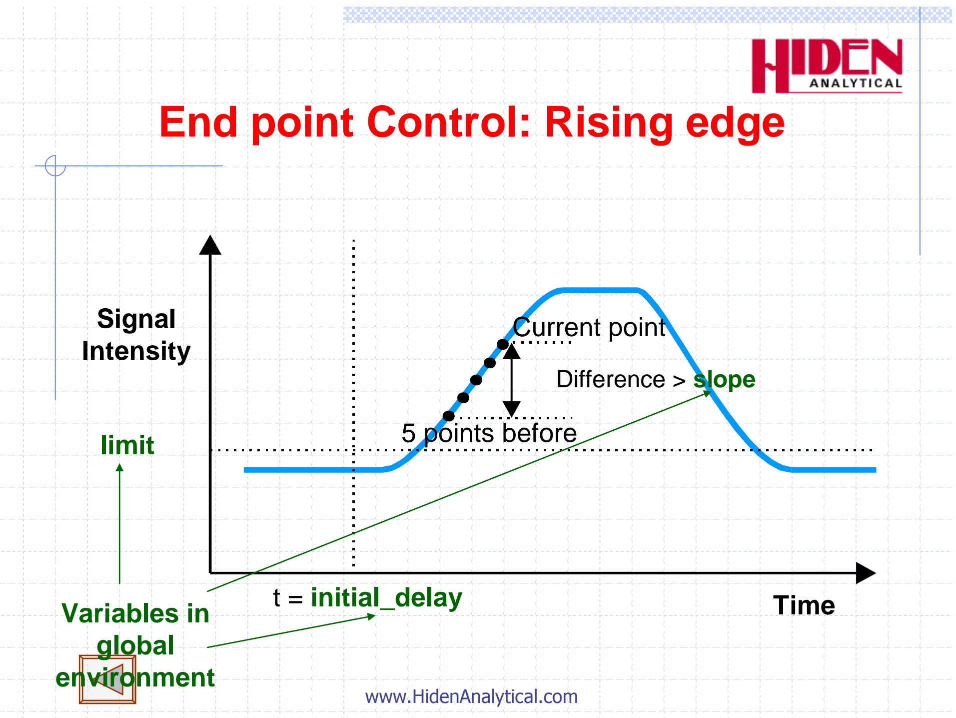
Set this to avoid the burst of signal that occurs after the shutter has opened.
If the first layer of the wafer is of the same material as the endpoint layer use the initial delay to avoiding finding endpoint on this layer.

limit



The slope and limit variables must be set so that endpoint is not found on small noise peaks at the start of the scan. The limit should be set just above the amplitude of the noise.

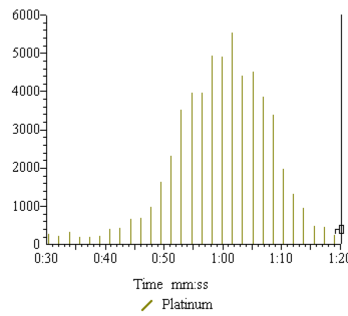
slope



This parameter may be set to avoid noise or signal variation causing a false endpoint.
In most cases this variable may be set to zero.

If the slope is set to zero endpoint may be found after any rising edge. When slope is zero the actual measured slope at the point where the limit is exceeded is written to the log at the end of the scan.

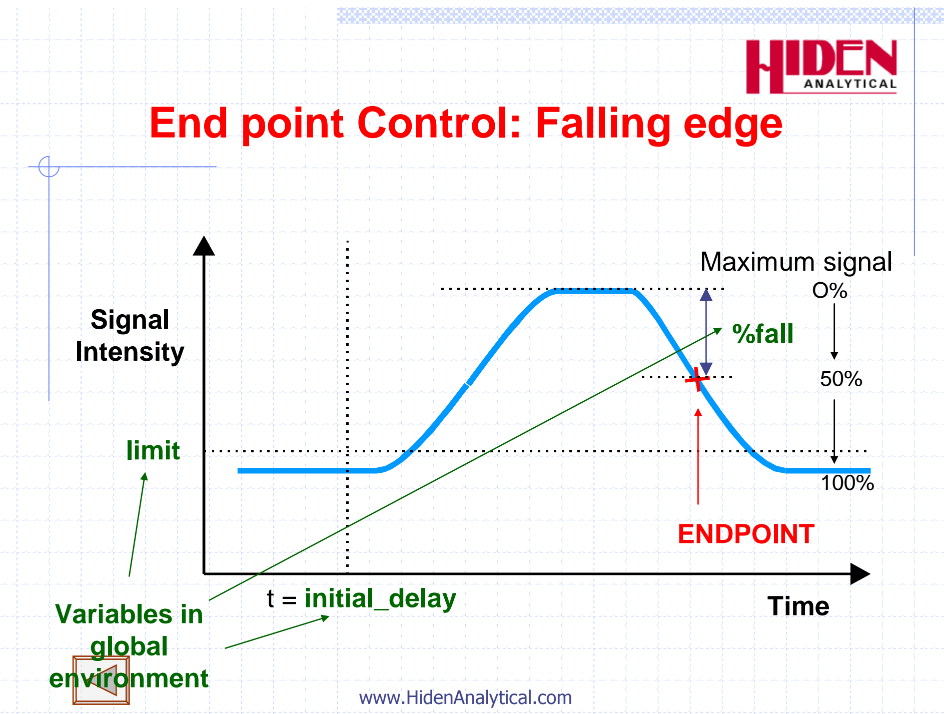
Alternatively the test etch file may be examined to establish an average slope per cycle on the rising edge of the endpoint layer.



To allow the individual points of the data to be seen create a view of the endpoint scan alone and use the Menu Bar **Views**, **Properties**, **Type**, option and select **Histogram graph**. Measure the difference in count rate over a set of 5 cycles on the rising edge of the peak close to the limit value, and set **slope** to 25 % of this value.

In the above example if the limit was 500 then the slope would be (1662 – 445) / 4 = ~ 300.

7.4. Falling Edge Variables

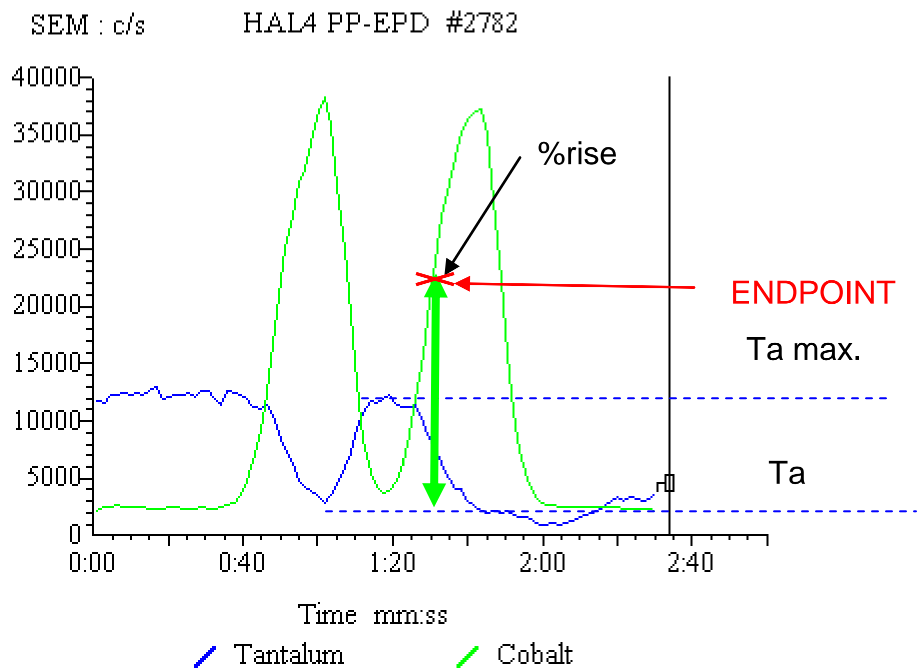


%fall

After the initial-delay has expired, the maximum signal level detected during the etch will be assumed to be 100 %. Set this value to be the percentage fall of this signal at which the endpoint should occur.

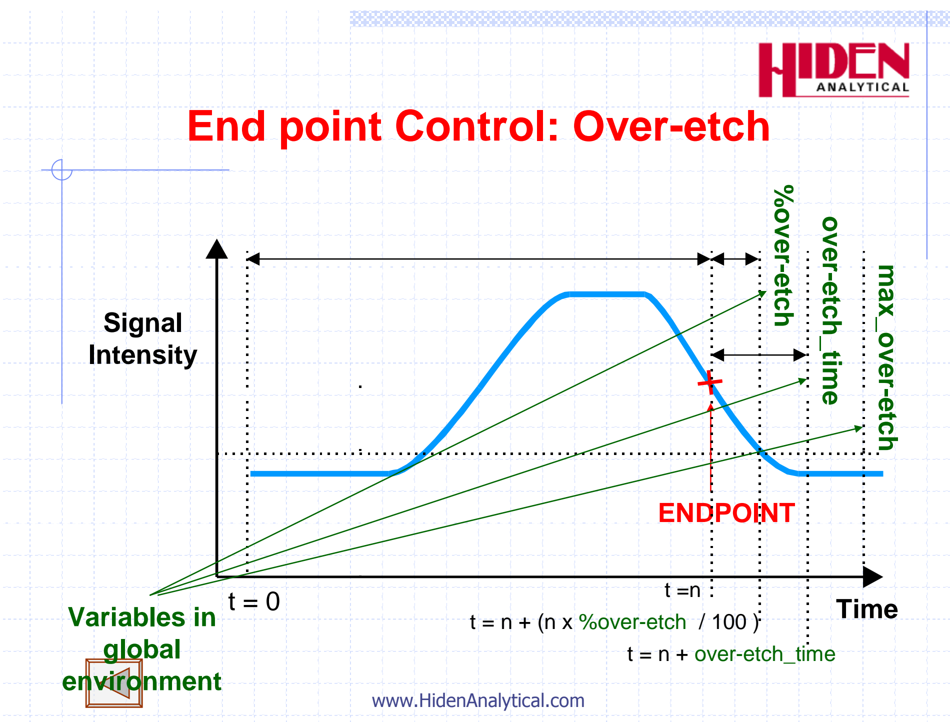
%fall (and %rise) calculations are with respect to the endpoint signal baseline (the lowest signal preceding the maximum but after the initial delay.)

The %fall may be calculated relative to a reference peak maximum (specified by reference-scan) instead of the endpoint peak itself (specified by endpoint-scan).



The %fall variable is also used on rising edge endpoints with a reference peak to hold the %rise value. The height of Ta peak is the maximum Ta signal minus the Ta baseline (the lowest Ta signal preceding the maximum but after the initial delay.)

7.5. Over-etch Variables



over-etch_time

If an absolute over-etch-time (i.e. a fixed number of seconds) is to be allowed before the endpoint signal goes true, set this parameter to this time. Fractional values can be used in this parameter.
If a percentage over-etch time is to be used, set this variable to **0**.

%over-etch

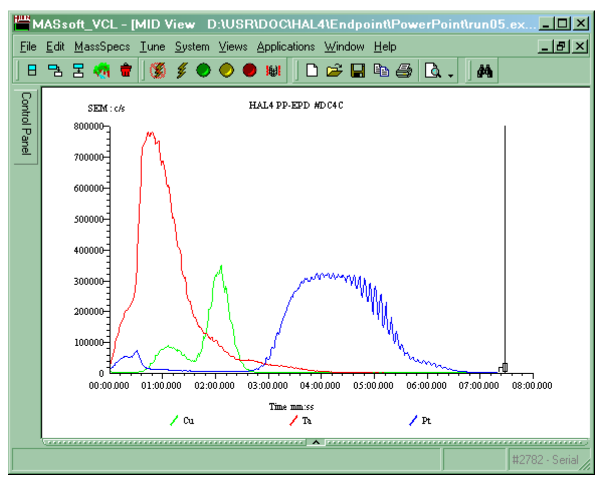
If an over-etch-time which is a percentage of the measured time from the start signal to the time at which the endpoint is detected, is to be allowed before the endpoint signal goes true, set this parameter to this percentage. If an absolute over-etch time is to be used, set this variable to **0**.

max_over-etch

Set this to the maximum allowable over-etch-time that should be needed. Avoids a percentage over-etch-time being too large.

7.6. Data averaging Variables

Variations due to rotation can cause the endpoint to be found too soon



average

The average variable can be used to reduce the effect of noise by averaging the readings from several cycles.
It will have less effect than RPM and period on rotation.
It only affects the values used by the endpoint event sequence so you will not see its effects in the display.

RPM

symmetry

The RPM and symmetry variables can be used to reduce the effect of rotation.

The period of rotation in ms is calculated by the formula
Period = 60000 / RPM

This is divided by the repetition due to symmetry to calculate the dwell in ms
Dwell = period / symmetry

By setting the endpoint scan’s dwell time to this value the data is averaged over one cycle of variation.

RPM and symmetry change the dwell, their affect will be seen in the displayed data.

7.7. Error checking Variables

warning-level

Set the warning-level to the minimum acceptable peak height for the endpoint layer.

7.8. Other Variables

step

The step variable must be set to zero. The step variable is set by the Script Interpreter script.

8. Creating a Template file

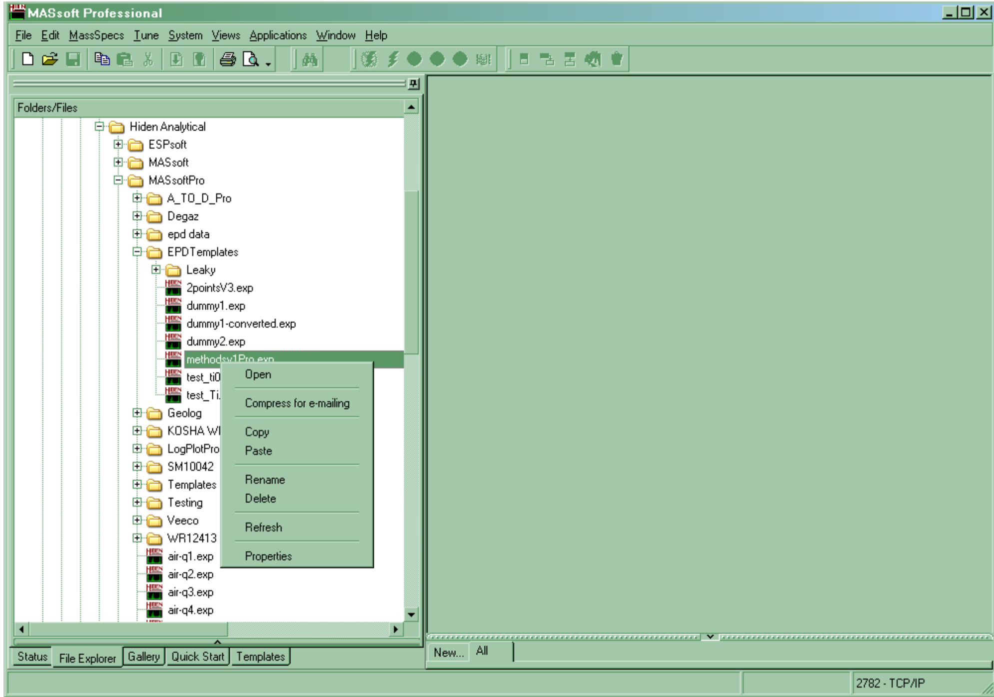
8.1. General

At this point, the mass spectrometer has been set up to acquire the strongest signal from
the wafer, and a template file may now be created.

A template contains information which tells the EPD which ions to monitor and how to
detect the endpoint. MASsoft files do not normally contain endpoint detection sequences, so to create a new template it is necessary to copy and modify an existing template. A new system will always contain at least one template provided by Hiden Analytical Limited.

- Copy an existing MASsoft Template file in order to copy the Event Sequence.
- Ensure the current multiplier voltage is used.
- Check the tuned lens values in the Global Environment
- Edit the Scan Tree to include the ions that you wish to monitor.
- Add Views to the Scan so you can see the data
- Run a wafer and determine the endpoint settings.
- Select an endpoint method.
- Specify the ion that you want to endpoint on.
- Enter the Endpoint settings into the Global Environment

8.2. Copying an existing template file



To copy an existing template file to a new template file:

1. Select the File Explorer Tab in the Control Tabs
2. Navigate to the EPD Template folder. Hiden supplied templates are stored in C:\Data Files\Hiden Analytical\MASsoftPro\EPDTemplates
3. Select the template that you want to copy e.g MethodsPro.exp
4. Using the right mouse button bring up the pop-up menu and select Copy
5. Select the template folder itself.
6. Using the right mouse button bring up the pop-up menu and select Paste
7. The file MethodsPro.exp will be copied to Copy of MethodsPro.exp
8. Select Copy of MethodsPro.exp
9. Using the right mouse button bring up the pop-up menu and select Rename
10. Enter the new name for the template file. Give the template a meaningful name for ease of use later.

Note:
Using the File Explorer tab in MASsoft ensures that all 5 files that constitute a MASsoft Experiment file are copied.

Alternatively the file may be opened using File, Open from the Menu Bar, and then saved under a new name using File, Save As.

Note:
Do not use File, Save as Template to save EPD Templates.

8.3.Checking the new template file

The new template file must now be checked to ensure that the optimum environment
values are used.

This is especially important when using older Templates from previous versions of MASsoft. Previous versions of MASsoft held the current multiplier voltage and tuned SIMS variables in the Global Environment, MASsoft Pro normally holds these values in the instrument environment. Steps 7 and 8 must be followed to ensure that these variables are taken from the Instrument Environment.

If the new template has been created by copying a Hiden supplied file, the file will require to be “Converted” to your instrument (see step 2) and the Global Environment values may need modification.

1. Open the template file by double-clicking on it in the File Explorer or by selecting **File, Open** from the Menu Bar.
2. If the file was created on a different instrument then convert the file by using the Convert tool on the tool bar or by selecting **File, Convert File** from the Menu Bar.
3. If the file is locked unlock the file using the Unlock tool on the tool bar or by selecting **File, Unlock** from the Menu Bar.
4. In the Scan Tree window double-click on the **Global:** box. The **Global Environment Editor** dialogue box is invoked.
5. Select the **+ion SIMS** tab.
6. Ensure that the **Default mode** is set to **+ion SIMS**. The default mode is marked by a tick in the tab, . To change mode select the **+ion SIMS** tab and then click on the **Default mode** checkbox.

7. Ensure that the current multiplier voltage voltage is being used. The **multiplier** variable in the **Detector** group should have its “Use” check box unchecked so that it is using the value from the Instrument Environment; this will be necessary when using files from an earlier version of MASsoft.

8. Ensure that the global SIMS environment variables are set to the latest tuned values. The tuned values are all in the **Filter** group.

   Where the new template has been created from one already in use on the tool, the environment values should already be optimum.

Usually the tuned values will be stored in the Instrument Environment, to use these values the SIMS environment variables should have their “Use” check boxes unchecked; this will be necessary when using files from an earlier version of MASsoft.

If the Template requires values that have been tuned for the particular stack then these may be imported from the .tun tune file saved at the end of the autotune procedure.

To do this exit the Global Environment Editor by clicking on the OK button to save the new settings. Select the Global Environment in the Scan Tree, then use the **File, Import, Environment, Tuned values** command from the Menu Bar. After importing the values repeat steps 6 & 7 to ensure that the values are correct. Imported tuned values will have their “Use” checkbox checked; these values will take precedence over the values in the Instrument Environment.

9. Set the **initial-delay endpoint** variable to 36000 s. This ensures that the EPD will not find an endpoint and cause the etch module to end the run prematurely. <u>This variable must be changed to the correct value when the endpoint criteria have been determined</u>.
10. Select the **OK** push-button. The **Environment Editor** dialogue box is closed.
11. Ensure that the file has Views. If the scans have been edited the views will have been deleted. If the Views have been deleted then select all the scans in the Scan Tree (use the Ctrl key to perform a multiple selection) then click on the Views tool, , on the Tool Bar.

Note: The template file must have a View:1 ; if View:1 is missing the Script Intepreter will not be able to open a link to control the run. If View:1 is missing delete all the views then create new ones

.

12. Save the file using **File, Save** from the Menu Bar.

8.4. Editing the new template file

To fully define MASsoft's automatic endpoint detection event sequence, a wafer stack needs to be milled completely through in order to determine the correct parameter values to use.

Test wafers should ideally contain similar materials and levels of masking as production wafers.

In the template file, although it is not necessary to create a scan tree to monitor all the masses present in the wafer, it is advisable to select one element's mass to represent each layer; the scan tree should contain one mass scan for each layer. Table 5 shows the masses of some typical etch products.

The masses of the ions of other elements may be obtained from the pop-up periodic table in the Scan Editor. Usually the mass of the most abundant isotope should be used.

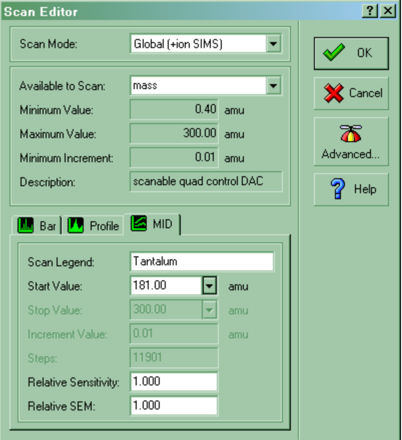
Other masses may be obtained from Hiden Analytical Limited if the required ion is not shown.

Layer	**Mass to monitor**	**Mass number (amu)**
AlTiC	Ti	48
CoFe	Co	59
Al_2O_3	Al/AlO	27/43
Ta	Ta	181
NiFe	Ni	58
Cu	Cu	63
FeMn	Mn	55
Co	Co	59
Ca	Ca	40
Ti	Ti	48
Cr	Cr	52
Ag	Ag	107
Au	Au	197
Pt	Pt	195
Si	Si/SiO	28/44

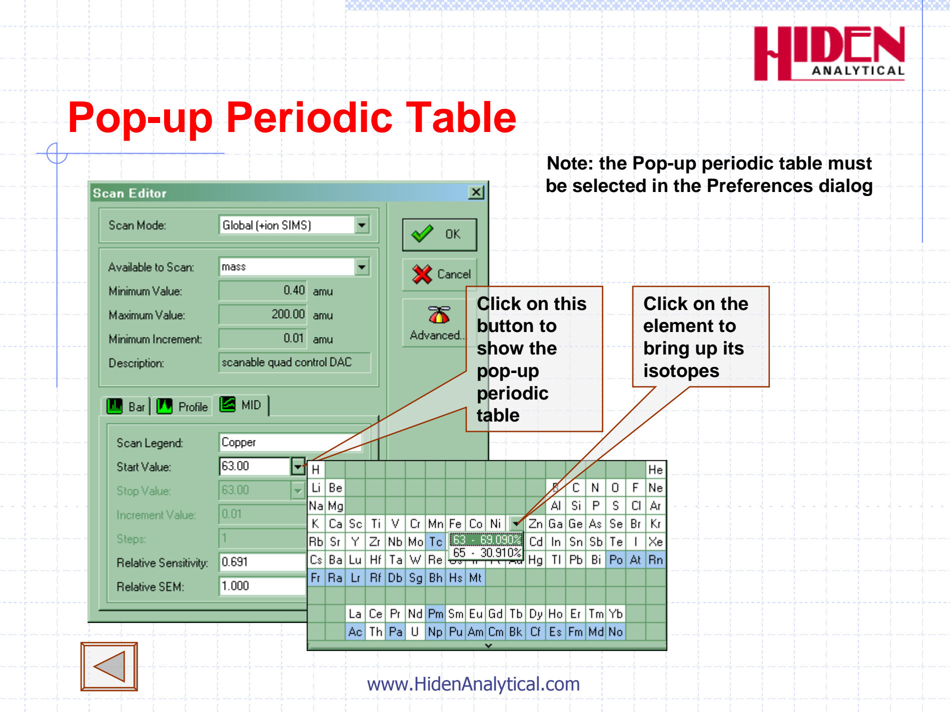
Table 5 Typical etch product monitor ions

Although auto endpoint criteria evaluate the trend of only one mass, monitoring each layer provides a real-time display of which layer the primary beam is currently etching through; this can often be used to help determine better endpoint criteria. For example, at a layer interface, it would be better to use the falling signal of the upper layer in preference to the rising signal of the lower layer, as this allows a percentage fall to be specified, which cannot be done with a rising signal.

1. Double-click the chosen **Scan** box. The **Scan Editor** dialogue box is invoked.
2. Select the MID (Multiple Ion Detection) tab.



3. Change the **Start value** the required mass value. The pop-up periodic table may be invoked by the button to do this.



When using the pup-up periodic table the Scan Legend, mass and Relative Sensitivity are all entered automatically.

The Relative Sensitivity (RS) is set to the isotopic abundance. However you are advised to change this value to 1.0 because the RS is only applied to displayed values, it is not applied to the values used by the

Interface Unit for endpointing. This will lead to a discrepancy between the displayed values and endpoint variables like **slope** and **limit**.

4. Enter a new **Scan legend** to make it easy to identify the layer.
5. Ensure the Relative Sensitivity is set to 1.0
6. Select the **OK** push-button. The **Scan Editor** dialogue box is closed.

To add a mass scan to the scan tree (for an additional layer):

1. Select the last **Scan** box in the scan tree, by clicking on it.
2. Select the Tool Bar **Next scan** tool . A new **Scan** is added to the scan tree.
3. Select the required mass for the scan, as shown above.

To delete a mass scan from the scan tree:

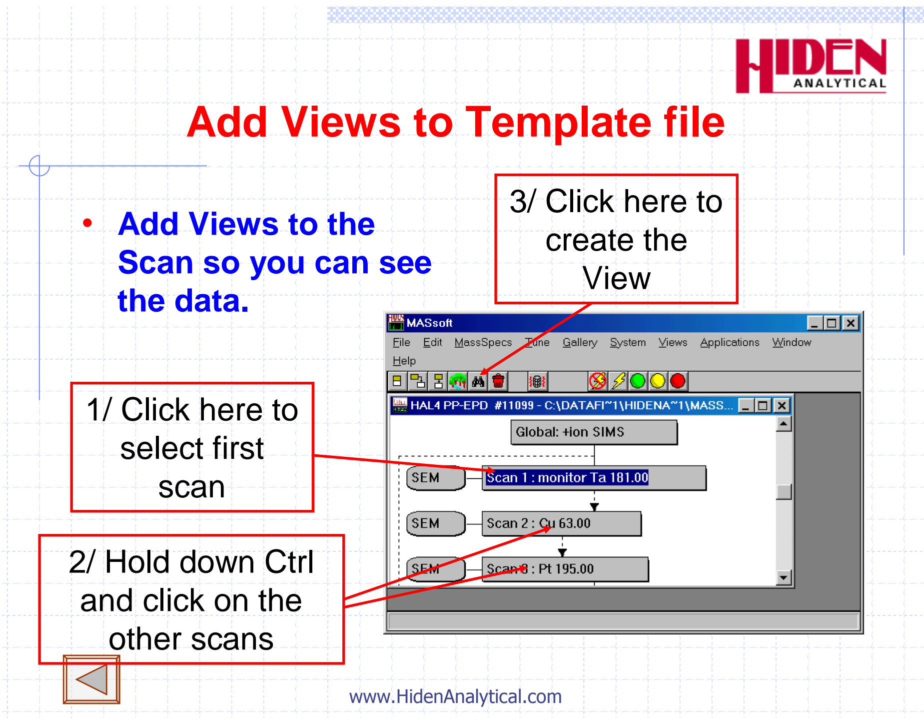
1. Select the required **Scan** box in the scan tree, by clicking on it.
2. Select the Tool Bar **Delete** tool, . The **Scan** is deleted from the scan tree.

Note that the first scan in the tree cannot be deleted.

It is recommended that the **Dwell Time** (the time used to acquire a single point in the scan) for each scan is set to 250 ms for the initial tests:

1. Double-click on the **SEM** input device box. The **Input Selection** dialogue box is invoked.
2. Select the Dwell Time **mS** radio button.
3. Enter ***250*** in the **Dwell Time** text box.
4. Select the **OK** push-button. The **Input Selection** dialogue box is closed.

When the scan tree is edited, any attached views are automatically deleted. To attach a view to each of the scans in the scan tree:



1. Click on the first **Scan** box.
2. Hold down the ***ctrl*** key.
3. Click on each of the other Scan boxes in turn. This will select all of the scans.
4. Select the Tool Bar **Attach view** tool, . A new view is created for each scan.

To close and save the template file:

1. Select the **File**, **Close** command.
2. Select the **Yes** push-button. The file is closed and saved.
3. Use Windows **Explorer** to set the files for each template to be read-only. This prevents the files being overwritten.

Note:

A template comprises five files; each has the same name, but there are different extension names: ***.ann**, ***.dat**, ***.env**, ***.exp** *and* ***.scn**. *All five files must be set to read-only.*

Currently (MASsoft 6.13) setting the file to read-only in the Properties pop-up of the File Explorer Tab in MASsoft only sets the .exp file to read-only

When the Template has been created a corresponding Script File must be created.

It is strongly recommended that the script file be given the same base name as the experiment file e.g. if the template is called Template.exp the script file should be name Template.run

The endpoint step number in the script file must match the process step number that ends by endpoint.

Before the Template file can be used in production the endpoint parameters need to be determined. These parameters are best determined by examining the data produced by etching a wafer.

8.5. To run a template manually

To determine the endpoint parameters it is necessary to acquire data from the etch of a wafer using the new template file.

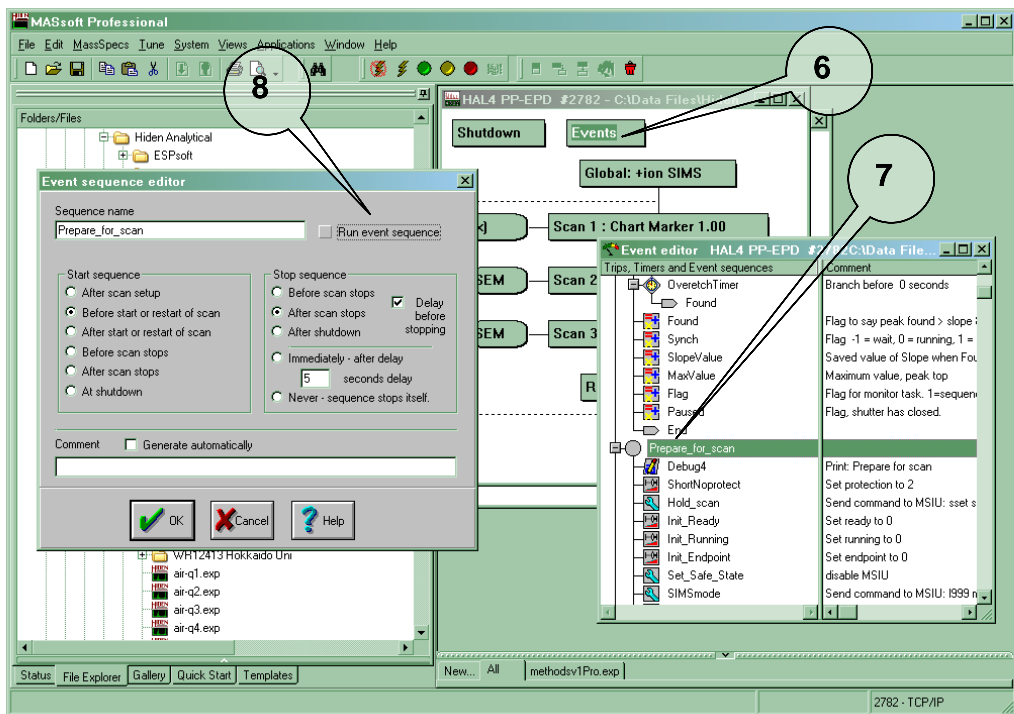
The template file is now ready to be run, but the steps required to start it automatically
from the etch module process controller have not yet been performed.

To acquire data you must either set up a Script Interpreter script to run the template and run it from a PM recipe or the wafer may be etched under manual control.

If the wafer is etched under manual control the PM will not send a start signal to IMP_EPD so the IMP-EPD will not acquire data. To acquire data manually the event sequence in the Template file that waits for the start signal must be disabled and the template must be manually run from MASsoft.

To run manually proceed as follows:

1. Copy the required template file, as described in Section 7.5.2.
2. Make a copy in a temporary folder. The file will be deleted after use.
3. Select the Menu Bar **File**, **Open** command. The **Open** dialogue box is invoked.
4. Select the template file, copied in Step 1.
5. Select the **OK** push-button. The file is opened.



6. Click on the scan tree window.
7. Double-click on the **Events** box. The **Event editor** window is invoked.
8. Double-click on the **Prepare_for_scan** event sequence marker.
9. The **Event sequence editor** dialogue box is invoked.
10. Deselect the **Run event sequence** option. This stops the task from running when the scan is started. The template file will not wait for a start signal from the PM or pause if the shutter is closed.
11. Select the **OK** push-button. The **Event sequence editor** dialogue box is closed.

12. Ensure that a test wafer is in position and ready to etch (beam on but shutter closed).
13. Select the Tool Bar **Go** tool, ,(green).
14. MASsoft downloads the scan parameters to the EPD.
15. Before data acquisition starts, the **Data Acquisition** dialogue box is invoked.
16. Enter a file name, or accept the default name offered. MASsoft generates default file names by using a number at the end of the existing name.
17. Select the **OK** push-button. Parameter download completes and MASsoft displays the status **Acquisition in progress** on the Status line at the bottom left of the MASsoft window (this may take about 30 seconds).

18. Data acquisition will not now wait for the **Start** signal but will begin immediately. When data acquisition starts begin the etch (open the shutter).

19. When the last layer has been etched, press the Tool Bar **Abort** tool, ,(red). Acquisition stops. The View shows the trend of each of the ions monitored. The resultant data file will be stored in the template folder.
20. Delete or move the template copy after endpoint parameters have been determined.

8.6. Entering the Endpoint Variables

After running an etch manually examine the data. Decide on an endpoint method as described in part 6 and determine the endpoint variables as described in part 7.

Enter the endpoint variables into the new template as follows:

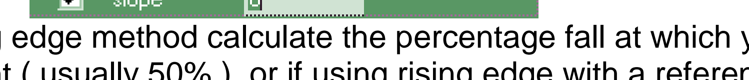
1. Open the template file by double-clicking on it in the File Explorer or by selecting **File, Open** from the Menu Bar.
2. Click on the scan tree window.
3. In the Scan Tree window double-click on the **Global:** box. The **Global Environment Editor** dialogue box is invoked.
4. Enter the method variable.

5. Choose the mass to be used for endpoint and find its scan. If a falling edge endpoint is being used this will be the layer preceding endpoint, if a rising edge it will be the layer after. Enter the scan number into endpoint-scan

6. If a reference scan is being used for percent rise or percent fall then enter the scan number into reference-scan, otherwise enter 0.

7. Examine the data for the endpoint-scan and determine the peak to peak baseline noise (difference between highest and lowest noise peak). Enter a value larger than this as the limit.

8. Initially you a recommended to enter a value of zero for the slope. If the endpoint proves susceptible to finding endpoint prematurely on noise or baseline drift then a slope value may help to prevent this. When the slope is zero the template will log the actual slope at the limit, to suppress this use a slope of 1.

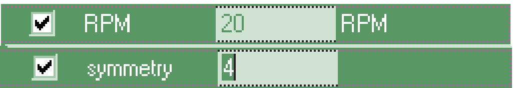


9. If using a falling edge method calculate the percentage fall at which you wish to endpoint (usually 50%), or if using rising edge with a reference peak calculate the percentage rise (may be greater than 100%). Enter the value into %fall.

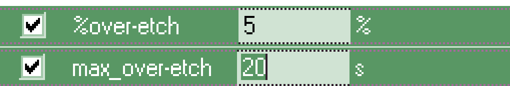
10. Set the initial delay to avoid peaks that occur when the shutter opens and to skip the first layer if this is the same material as the endpoint layer.

11. If there is more than one layer of the endpoint layer material the endpoint-layer variable may be used with methods 11-15 or 21-25.

12. To reduce the effect of rotation the RPM and symmetry variables may be entered. These will over-ride the dwell time specified in the endpoint scan unless RPM is zero.



13. To reduce the noise on the signal the data may be averaged over more than one cycle. Note: this will delay the detection of endpoint, so may require a reduction in the over-etch time.
14. To over-etch for a fixed length of time enter the over-etch time in seconds.
15. Alternatively the over-etch time may be entered as a percentage of the etch time at endpoint. The max_over-etch variable sets an upper limit for the time calculated from the %over-etch.



16. Finally set the warning-level to the minimum acceptable peak height for the endpoint layer.

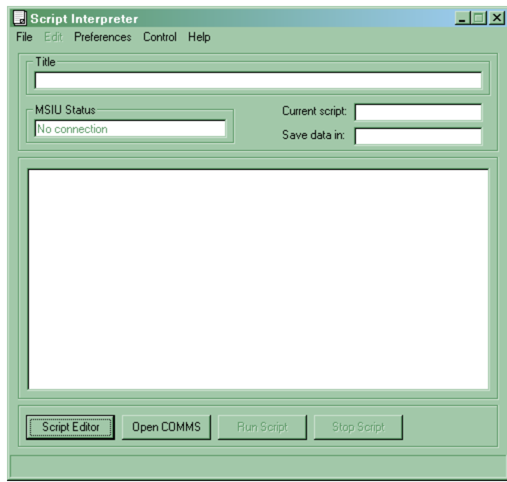
17. Click on OK to close the Global Environment Editor.
18. Save the changes using **File,Save** from the Menu Bar.

8.7. Creating The Script File

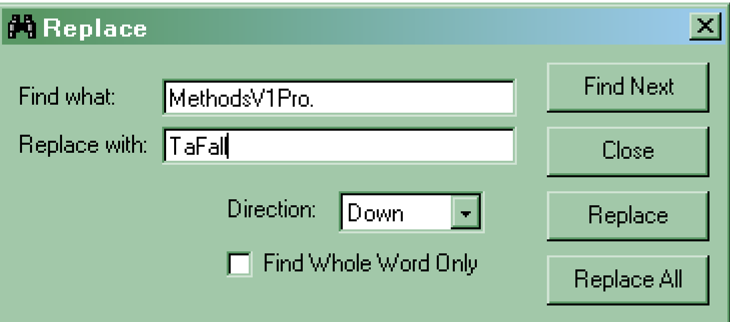
Once the Template file has been created the Script Interpreter Script file should be created. This is done by copying an existing script and modifying it. The Method template must be used with the corresponding Method script. There a 6 pre-prepared scripts called MethodsV1ProStep1.run to MethodsV1ProStep6.run for endpointing on process steps 1 to 6.

1. Switch to the Script Interpreter using **Applications, Script Interpreter** from the Menu Bar in MASsoft.

2. The Script Interpreter window will be displayed.



3. Click on the Script Editor button. The button will change caption to “Script Interpreter” and the other buttons will be greyed. The Edit menu is enabled.
4. Using the **File Open** command from the Menu Bar open the appropriate pre-prepared script, MethodsV1ProStep1.run … MethodsV1ProStep6.run.
5. Before modifying the file use the **File,Save As** command from the Menu Bar to save the file. The file should be given the same base name as the Template file. E.g. if the Template is called TaFall.exp the script should be called TaFall.run
6. Use the Edit, Replace command from the Menu Bar to edit the script
7. Replace all occurrences of MethodsV1Pro with the name of the new template.



8. Click on the **Replace All** button. When the replacements have been made

9. is displayed. Click on **OK**.
10. Click on Close to exit the Replace dialog.
11. Use the **File, Save** command to save the script.

12. Finally click on the Script Interpreter button to leave the Script Editor.

13. The Script and Template are now ready to be run automatically.

8.8. Creating a Template file

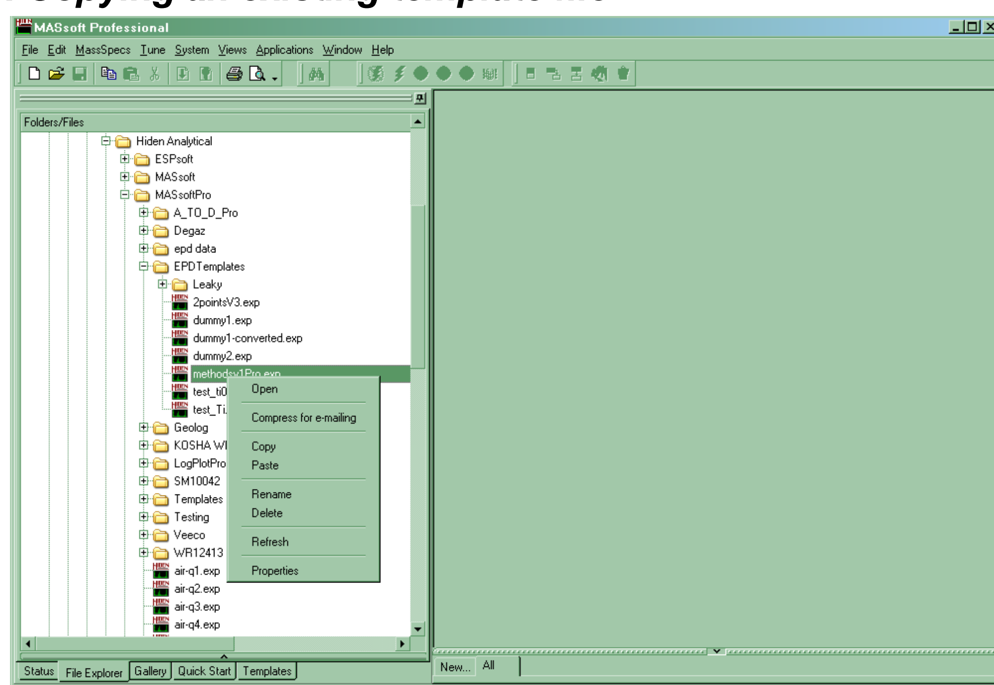
8.9. General

At this point, the mass spectrometer has been set up to acquire the strongest signal from
the wafer, and a template file may now be created.

A template contains information which tells the EPD which ions to monitor and how to
detect the endpoint. MASsoft files do not normally contain endpoint detection sequences, so to create a new template it is necessary to copy and modify an existing template. A new system will always contain at least one template provided by Hiden Analytical Limited.

- Copy an existing MASsoft Template file in order to copy the Event Sequence.
- Ensure the current multiplier voltage is used.
- Check the tuned lens values in the Global Environment
- Edit the Scan Tree to include the ions that you wish to monitor.
- Add Views to the Scan so you can see the data
- Run a wafer and determine the endpoint settings.
- Select an endpoint method.
- Specify the ion that you want to endpoint on.
- Enter the Endpoint settings into the Global Environment

8.10. Copying an existing template file



To copy an existing template file to a new template file:

11. Select the File Explorer Tab in the Control Tabs
12. Navigate to the EPD Template folder. Hiden supplied templates are stored in C:\Data Files\Hiden Analytical\MASsoftPro\EPDTemplates
13. Select the template that you want to copy e.g MethodsPro.exp
14. Using the right mouse button bring up the pop-up menu and select Copy
15. Select the template folder itself.
16. Using the right mouse button bring up the pop-up menu and select Paste
17. The file MethodsPro.exp will be copied to Copy of MethodsPro.exp
18. Select Copy of MethodsPro.exp
19. Using the right mouse button bring up the pop-up menu and select Rename
20. Enter the new name for the template file. Give the template a meaningful name for ease of use later.

Note:
Using the File Explorer tab in MASsoft ensures that all 5 files that constitute a MASsoft Experiment file are copied.

Alternatively the file may be opened using File, Open from the Menu Bar, and then saved under a new name using File, Save As.

Note:
Do not use File, Save as Template to save EPD Templates.

8.11.Checking the new template file

The new template file must now be checked to ensure that the optimum environment
values are used.

This is especially important when using older Templates from previous versions of MASsoft. Previous versions of MASsoft held the current multiplier voltage and tuned SIMS variables in the Global Environment, MASsoft Pro normally holds these values in the instrument environment. Steps 7 and 8 must be followed to ensure that these variables are taken from the Instrument Environment.

If the new template has been created by copying a Hiden supplied file, the file will require to be “Converted” to your instrument (see step 2) and the Global Environment values may need modification.

13. Open the template file by double-clicking on it in the File Explorer or by selecting **File, Open** from the Menu Bar.
14. If the file was created on a different instrument then convert the file by using the Convert tool on the tool bar or by selecting **File, Convert File** from the Menu Bar.
15. If the file is locked unlock the file using the Unlock tool on the tool bar or by selecting **File, Unlock** from the Menu Bar.
16. In the Scan Tree window double-click on the **Global:** box. The **Global Environment Editor** dialogue box is invoked.
17. Select the **+ion SIMS** tab.
18. Ensure that the **Default mode** is set to **+ion SIMS**. The default mode is marked by a tick in the tab, +ion SIMS. To change mode select the **+ion SIMS** tab and then click on the **Default mode** checkbox.

19. Ensure that the current multiplier voltage voltage is being used. The **multiplier** variable in the **Detector** group should have its “Use” check box unchecked so that it is using the value from the Instrument Environment; this will be necessary when using files from an earlier version of MASsoft.

20. Ensure that the global SIMS environment variables are set to the latest tuned values. The tuned values are all in the **Filter** group.

    Where the new template has been created from one already in use on the tool, the environment values should already be optimum.

Usually the tuned values will be stored in the Instrument Environment, to use these values the SIMS environment variables should have their “Use” check boxes unchecked; this will be necessary when using files from an earlier version of MASsoft.

If the Template requires values that have been tuned for the particular stack then these may be imported from the .tun tune file saved at the end of the autotune procedure.

To do this exit the Global Environment Editor by clicking on the OK button to save the new settings. Select the Global Environment in the Scan Tree, then use the **File, Import, Environment, Tuned values** command from the Menu Bar. After importing the values repeat steps 6 & 7 to ensure that the values are correct. Imported tuned values will have their “Use” checkbox checked; these values will take precedence over the values in the Instrument Environment.

21. Set the **initial-delay endpoint** variable to 36000 s. This ensures that the EPD will not find an endpoint and cause the etch module to end the run prematurely. This variable must be changed to the correct value when the endpoint criteria have been determined.
22. Select the **OK** push-button. The **Environment Editor** dialogue box is closed.
23. Ensure that the file has Views. If the scans have been edited the views will have been deleted. If the Views have been deleted then select all the scans in the Scan Tree (use the Ctrl key to perform a multiple selection) then click on the Views tool, , on the Tool Bar.

Note: The template file must have a View:1 ; if View:1 is missing the Script Intepreter will not be able to open a link to control the run. If View:1 is missing delete all the views then create new ones

.

24. Save the file using **File, Save** from the Menu Bar.

8.12. Editing the new template file

To fully define MASsoft's automatic endpoint detection event sequence, a wafer stack needs to be milled completely through in order to determine the correct parameter values to use.

Test wafers should ideally contain similar materials and levels of masking as production wafers.

In the template file, although it is not necessary to create a scan tree to monitor all the masses present in the wafer, it is advisable to select one element's mass to represent each layer; the scan tree should contain one mass scan for each layer. Table 5 shows the masses of some typical etch products.

The masses of the ions of other elements may be obtained from the pop-up periodic table in the Scan Editor. Usually the mass of the most abundant isotope should be used.

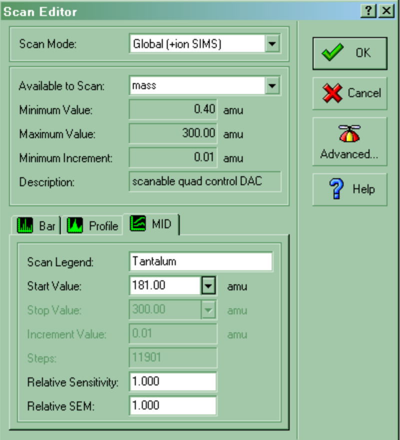
Other masses may be obtained from Hiden Analytical Limited if the required ion is not shown.

Layer	Mass to monitor	Mass number (amu)
AlTiC	Ti	48
CoFe	Co	59
Al_2O_3	Al/AlO	27/43
Ta	Ta	181
NiFe	Ni	58
Cu	Cu	63
FeMn	Mn	55
Co	Co	59
Ca	Ca	40
Ti	Ti	48
Cr	Cr	52
Ag	Ag	107
Au	Au	197
Pt	Pt	195
Si	Si/SiO	28/44

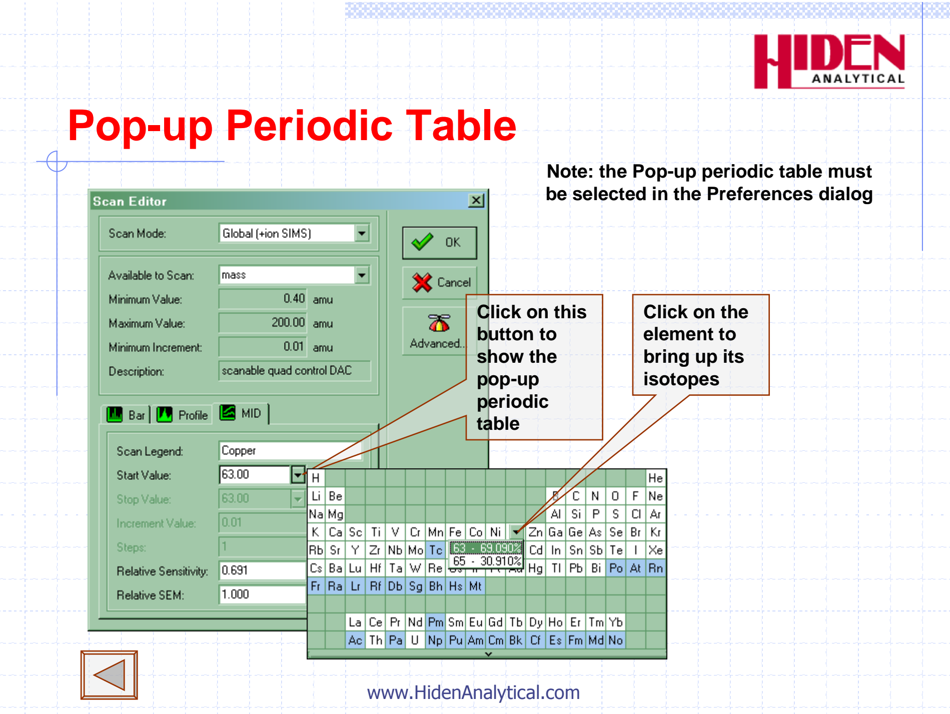
Table 5 Typical etch product monitor ions

Although auto endpoint criteria evaluate the trend of only one mass, monitoring each layer provides a real-time display of which layer the primary beam is currently etching through; this can often be used to help determine better endpoint criteria. For example, at a layer interface, it would be better to use the falling signal of the upper layer in preference to the rising signal of the lower layer, as this allows a percentage fall to be specified, which cannot be done with a rising signal.

7. Double-click the chosen **Scan** box. The **Scan Editor** dialogue box is invoked.
8. Select the MID (Multiple Ion Detection) tab.



9. Change the **Start value** the required mass value. The pop-up periodic table may be invoked by the button to do this.



When using the pup-up periodic table the Scan Legend, mass and Relative Sensitivity are all entered automatically.

The Relative Sensitivity (RS) is set to the isotopic abundance. However you are advised to change this value to 1.0 because the RS is only applied to displayed values, it is not applied to the values used by the

Interface Unit for endpointing. This will lead to a discrepancy between the displayed values and endpoint variables like **slope** and **limit**.

10. Enter a new **Scan legend** to make it easy to identify the layer.
11. Ensure the Relative Sensitivity is set to 1.0
12. Select the **OK** push-button. The **Scan Editor** dialogue box is closed.

To add a mass scan to the scan tree (for an additional layer):

4. Select the last **Scan** box in the scan tree, by clicking on it.
5. Select the Tool Bar **Next scan** tool . A new **Scan** is added to the scan tree.
6. Select the required mass for the scan, as shown above.

To delete a mass scan from the scan tree:

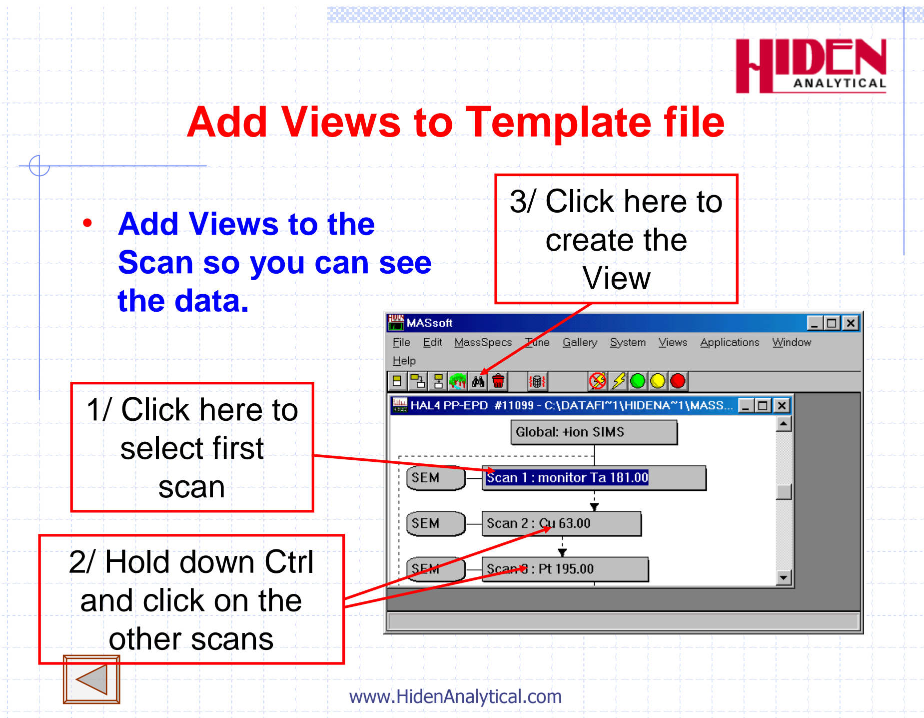
3. Select the required **Scan** box in the scan tree, by clicking on it.
4. Select the Tool Bar **Delete** tool, . The **Scan** is deleted from the scan tree.

Note that the first scan in the tree cannot be deleted.

It is recommended that the **Dwell Time** (the time used to acquire a single point in the scan) for each scan is set to 250 ms for the initial tests:

5. Double-click on the **SEM** input device box. The **Input Selection** dialogue box is invoked.
6. Select the Dwell Time **mS** radio button.
7. Enter ***250*** in the **Dwell Time** text box.
8. Select the **OK** push-button. The **Input Selection** dialogue box is closed.

When the scan tree is edited, any attached views are automatically deleted. To attach a view to each of the scans in the scan tree:



5. Click on the first **Scan** box.
6. Hold down the ***ctrl*** key.
7. Click on each of the other Scan boxes in turn. This will select all of the scans.
8. Select the Tool Bar **Attach view** tool, . A new view is created for each scan.

To close and save the template file:

4. Select the **File**, **Close** command.
5. Select the **Yes** push-button. The file is closed and saved.
6. Use Windows **Explorer** to set the files for each template to be read-only. This prevents the files being overwritten.

Note:

A template comprises five files; each has the same name, but there are different extension names: ***.ann**, ***.dat**, ***.env**, ***.exp** *and* ***.scn**. *All five files must be set to read-only.*

Currently (MASsoft 6.13) setting the file to read-only in the Properties pop-up of the File Explorer Tab in MASsoft only sets the .exp file to read-only

When the Template has been created a corresponding Script File must be created.

It is strongly recommended that the script file be given the same base name as the experiment file e.g. if the template is called Template.exp the script file should be name Template.run

The endpoint step number in the script file must match the process step number that ends by endpoint.

Before the Template file can be used in production the endpoint parameters need to be determined. These parameters are best determined by examining the data produced by etching a wafer.

8.13. To run a template manually

To determine the endpoint parameters it is necessary to acquire data from the etch of a wafer using the new template file.

The template file is now ready to be run, but the steps required to start it automatically
from the etch module process controller have not yet been performed.

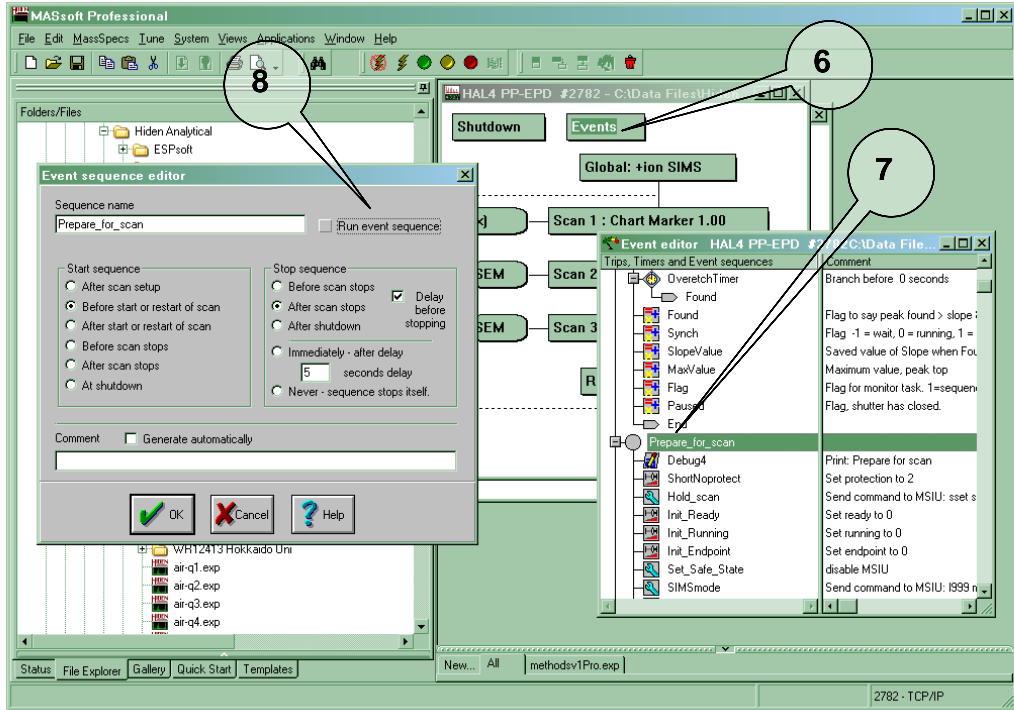
To acquire data you must either set up a Script Interpreter script to run the template and run it from a PM recipe or the wafer may be etched under manual control.

If the wafer is etched under manual control the PM will not send a start signal to IMP_EPD so the IMP-EPD will not acquire data. To acquire data manually the event sequence in the Template file that waits for the start signal must be disabled and the template must be manually run from MASsoft.

To run manually proceed as follows:

21. Copy the required template file, as described in Section 7.5.2.
22. Make a copy in a temporary folder. The file will be deleted after use.

23. Select the Menu Bar **File**, **Open** command. The **Open** dialogue box is invoked.
24. Select the template file, copied in Step 1.
25. Select the **OK** push-button. The file is opened.



26. Click on the scan tree window.
27. Double-click on the **Events** box. The **Event editor** window is invoked.
28. Double-click on the **Prepare_for_scan** event sequence marker.
29. The **Event sequence editor** dialogue box is invoked.
30. Deselect the **Run event sequence** option. This stops the task from running when the scan is started. The template file will not wait for a start signal from the PM or pause if the shutter is closed.
31. Select the **OK** push-button. The **Event sequence editor** dialogue box is closed.

32. Ensure that a test wafer is in position and ready to etch (beam on but shutter closed).
33. Select the Tool Bar **Go** tool, ,(green).
34. MASsoft downloads the scan parameters to the EPD.
35. Before data acquisition starts, the **Data Acquisition** dialogue box is invoked.
36. Enter a file name, or accept the default name offered. MASsoft generates default file names by using a number at the end of the existing name.
37. Select the **OK** push-button. Parameter download completes and MASsoft displays the status **Acquisition in progress** on the Status line at the bottom left of the MASsoft window (this may take about 30 seconds).

38. Data acquisition will not now wait for the **Start** signal but will begin immediately. When data acquisition starts begin the etch (open the shutter).

39. When the last layer has been etched, press the Tool Bar **Abort** tool, ,(red). Acquisition stops. The View shows the trend of each of the ions monitored. The resultant data file will be stored in the template folder.
40. Delete or move the template copy after endpoint parameters have been determined.

8.14. Entering the Endpoint Variables

After running an etch manually examine the data. Decide on an endpoint method as described in part 6 and determine the endpoint variables as described in part 7.

Enter the endpoint variables into the new template as follows:

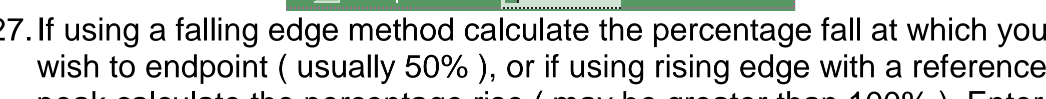
19. Open the template file by double-clicking on it in the File Explorer or by selecting **File, Open** from the Menu Bar.
20. Click on the scan tree window.
21. In the Scan Tree window double-click on the **Global:** box. The **Global Environment Editor** dialogue box is invoked.
22. Enter the method variable.

23. Choose the mass to be used for endpoint and find its scan. If a falling edge endpoint is being used this will be the layer preceding endpoint, if a rising edge it will be the layer after. Enter the scan number into endpoint-scan

24. If a reference scan is being used for percent rise or percent fall then enter the scan number into reference-scan, otherwise enter 0.

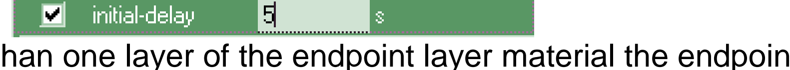
25. Examine the data for the endpoint-scan and determine the peak to peak baseline noise (difference between highest and lowest noise peak). Enter a value larger than this as the limit.

26. Initially you a recommended to enter a value of zero for the slope. If the endpoint proves susceptible to finding endpoint prematurely on noise or baseline drift then a slope value may help to prevent this. When the slope is zero the template will log the actual slope at the limit, to suppress this use a slope of 1.



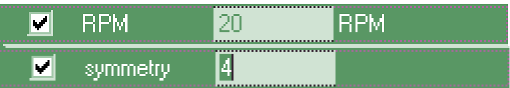
27. If using a falling edge method calculate the percentage fall at which you wish to endpoint (usually 50%), or if using rising edge with a reference peak calculate the percentage rise (may be greater than 100%). Enter the value into %fall.

28. Set the initial delay to avoid peaks that occur when the shutter opens and to skip the first layer if this is the same material as the endpoint layer.



29. If there is more than one layer of the endpoint layer material the endpoint-layer variable may be used with methods 11-15 or 21-25.

30. To reduce the effect of rotation the RPM and symmetry variables may be entered. These will over-ride the dwell time specified in the endpoint scan unless RPM is zero.



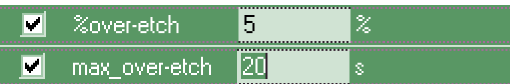
31. To reduce the noise on the signal the data may be averaged over more than one cycle. Note: this will delay the detection of endpoint, so may require a reduction in the over-etch time.

average 2

32. To over-etch for a fixed length of time enter the over-etch time in seconds.

over-etch_time 20 s

33. Alternatively the over-etch time may be entered as a percentage of the etch time at endpoint. The max_over-etch variable sets an upper limit for the time calculated from the %over-etch.



34. Finally set the warning-level to the minimum acceptable peak height for the endpoint layer.

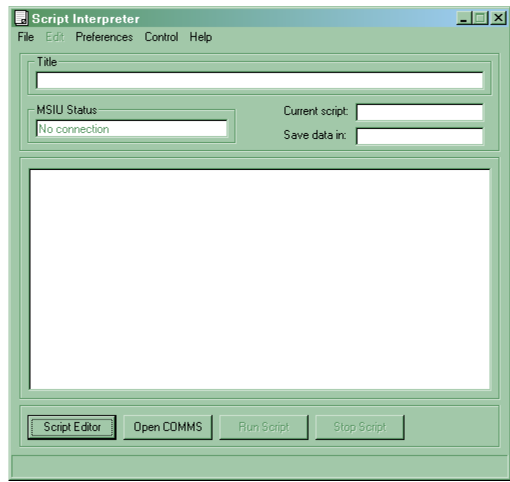
35. Click on OK to close the Global Environment Editor.
36. Save the changes using **File,Save** from the Menu Bar.

8.15. Creating The Script File

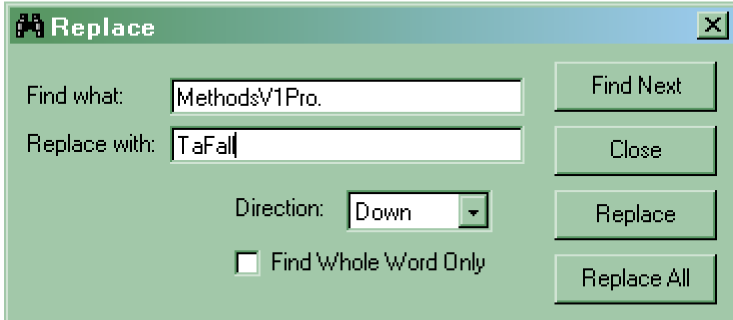
Once the Template file has been created the Script Interpreter Script file should be created. This is done by copying an existing script and modifying it. The Method template must be used with the corresponding Method script. There a 6 pre-prepared scripts called MethodsV1ProStep1.run to MethodsV1ProStep6.run for endpointing on process steps 1 to 6.

14. Switch to the Script Interpreter using **Applications, Script Interpreter** from the Menu Bar in MASsoft.

15. The Script Interpreter window will be displayed.



16. Click on the Script Editor button. The button will change caption to “Script Interpreter” and the other buttons will be greyed. The Edit menu is enabled.
17. Using the **File Open** command from the Menu Bar open the appropriate pre-prepared script, MethodsV1ProStep1.run … MethodsV1ProStep6.run.
18. Before modifying the file use the **File,Save As** command from the Menu Bar to save the file. The file should be given the same base name as the Template file. E.g. if the Template is called TaFall.exp the script should be called TaFall.run
19. Use the Edit, Replace command from the Menu Bar to edit the script
20. Replace all occurrences of MethodsV1Pro with the name of the new template.



21. Click on the **Replace All** button. When the replacements have been made

22. is displayed. Click on **OK**.
23. Click on Close to exit the Replace dialog.
24. Use the **File, Save** command to save the script.

25. Finally click on the Script Interpreter button to leave the Script Editor.

26. The Script and Template are now ready to be run automatically.

9. Running a template automatically

MASsoft will run a template automatically when the correct command sequence is sent by the PM to the Script Interpreter.
To run a template automatically, ensure that MASsoft and the Script Interpreter are running. The system will then:

- Obtain the script name from the Process Module.
- Locate and open the required template.
- Download the parameter values to the EPD.
- Acquire data and find endpoint.

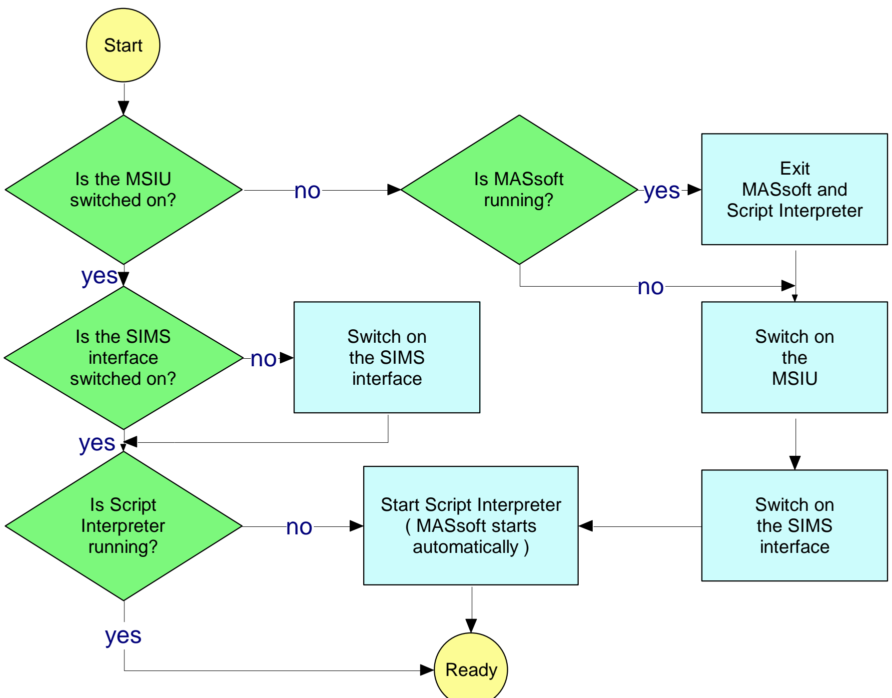
9.1. Starting MASsoft

The IMP-EPD must be started in the correct order.

The MSIU must be switched on before MASsoft starts because MASsoft needs to establish a network connection to the MSIU at startup.

It does not matter whether the MSIU or SIMS Interface is switched on first.

This flow chart shows the start up sequence.



Start MASsoft by clicking on the icon on the desktop or from the Start menu in Programs, Hiden Applications.

The Script Interpreter may be started from the Applications menu in the Menu Bar in MASsoft or from the Start menu in Programs, Hiden Applications.

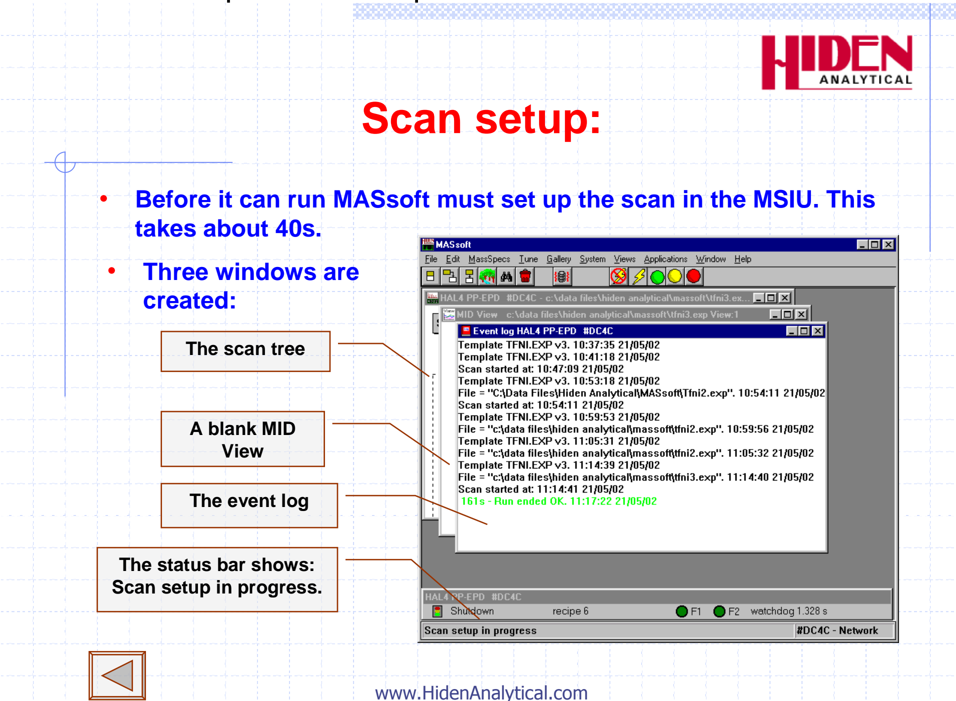
If the Script Interpreter is started first it will automatically start MASsoft.

9.2. Running a Template

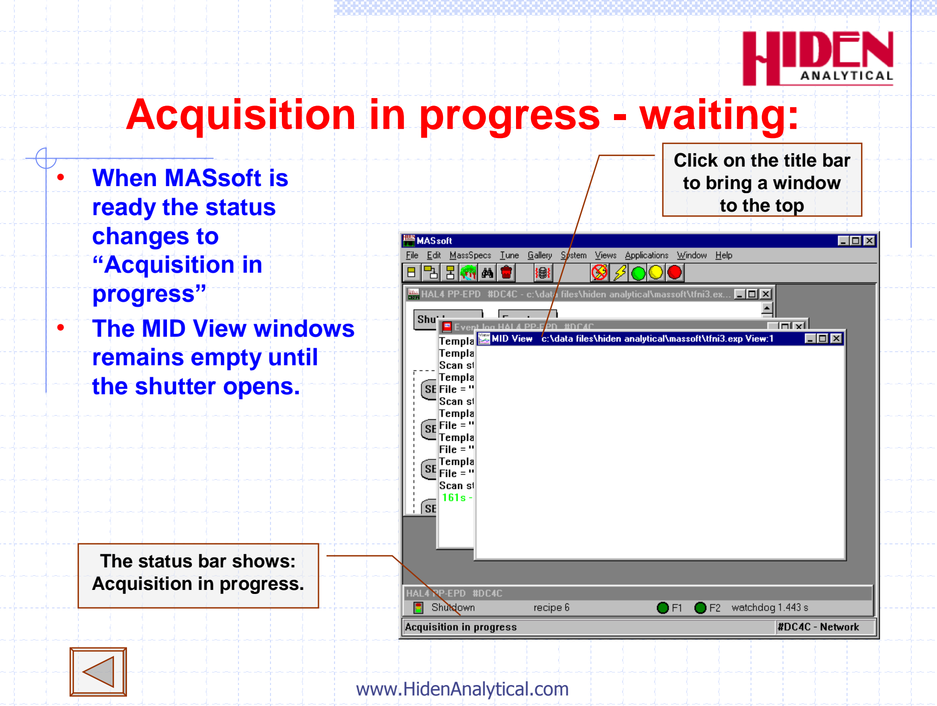
When MASsoft and Script Interpreter are running and the Template File and Script have been created the IMP-EPD is ready to start endpoint detection. The endpoint script is specified in the endpoint step of the process recipe. Running the endpoint template is entirely automatic, no further operator actions are required.

When the Script Interpreter receives the command to run the Template the following occurs.

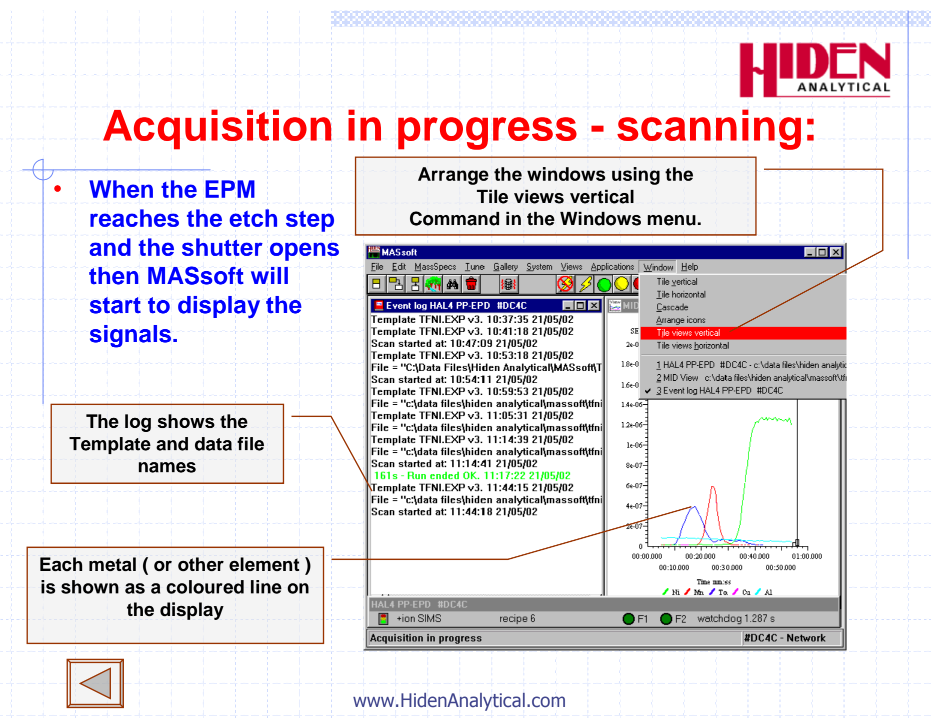
1. The Template File is opened and run.



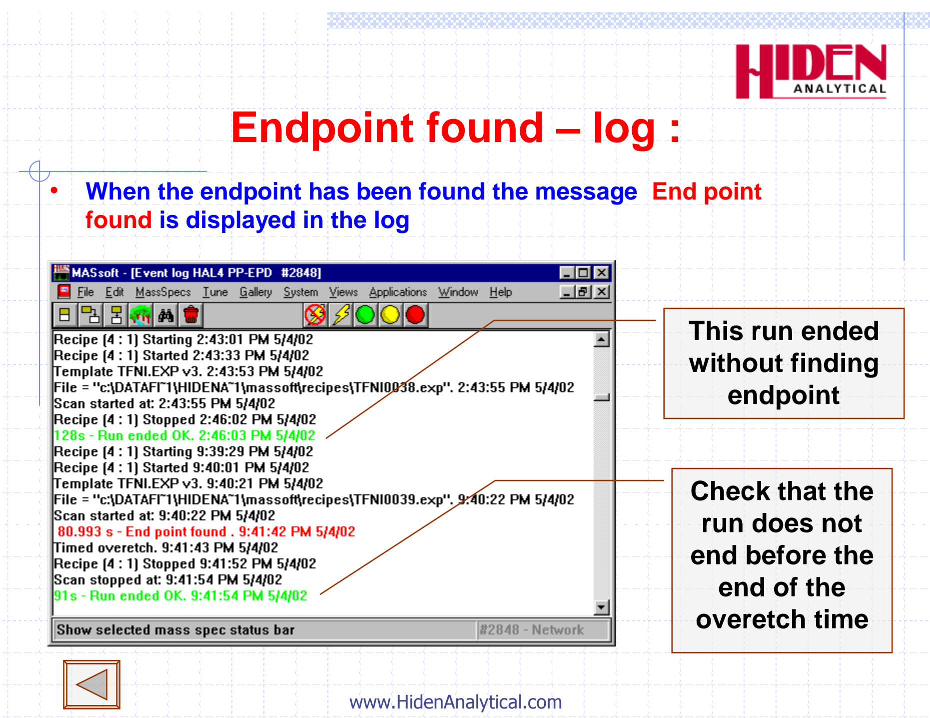
2. At this point MASsoft's Message line will display **Scan setup in progress** shortly followed by **Acquisition in progress**. No data will be displayed yet.



3. As the etch module begins the etch, it will send the Start command. At this point data will start to be acquired and displayed on the file's View. As these steps occur they will be displayed in the log window.



4. When the endpoint is detected, the time is logged and the over-etch time begins. As the over-etch timer expires, the **Endpoint** signal is set true. At this point, the etch module sends the Stop command and EPD monitoring stops.



10. Advanced Techniques

10.1. Local Environments

A Local Environment allows environment variable values to be specified that are specific to a scan. The Local Environment is the highest level of the Environment Hierarchy. A value set in the Local Environment takes precedence over values in the Global and Instrument Environments.

Environment variable values that are set in a Local Environment are applied while the scan is performing its measurement; the variables are restored to their original value before measurement of the next scan begins.

Only Analyser Control Variables should be set in the Local Environment. Endpoint Variables (if present) must not be set in the Local Environment.

It would not be unreasonable to expect that the Endpoint variables for the endpoint scan should be set in a Local Environment attached to the endpoint scan itself, but this is wrong. This is because the endpoint Event Sequence would only be able to read the correct endpoint variable values whilst the endpoint scan was performing its measurement; whilst any other scan was performing its measurement the wrong value would be read.

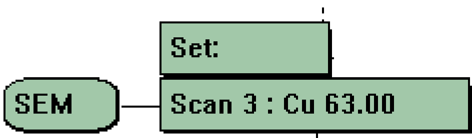
10.1.1. Note For Users of Previous Versions of MASsoft.

In previous versions of MASsoft all Local Environments had to be deleted if any variables in the Global Environment were changed because the variables retained their old values in the Local Environment. Variables were implicitly set in the Local Environment if their value differed from the value in the Global Environment.

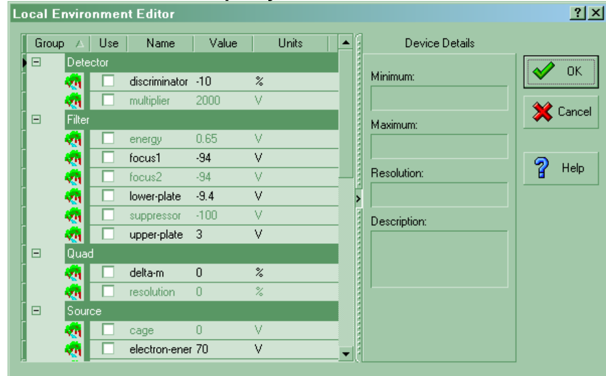
In MASsoft Pro this is no longer necessary. Local variables in the Local Environment are now explicitly specified by the “Use” check box. All variables that do not have their “Use” check box checked will take their value from Environments lower in the Environment Hierarchy. If a value in the Global environment changes it will also change in the Local Environment unless the variable’s “Use” checkbox is checked in the Local Environment.

10.1.2. Adding a Local Environment to a Scan

1. Select the Scan Tree window.
2. In the Scan Tree select the scan and click on the Environment tool, on the Tool Bar .
3. A Local Environment will be added to the scan, this is indicated by the box labelled **Set:**



4. To edit the Local Environment double-click on the Set: box. The Local Environment Editor will be displayed.



5. The Local Environment only contains one set of values for one mode; the Mode (RGA or +ion SIMS) of the Local Environment is the same as the Mode of the scan.

6. Initially all the variables have their "Use" check-box unchecked. When you enter a value the check-box becomes checked. Un-checking the check-box will revert to the Global Environment value.

7. Click on **OK** to accept any changes and close the Local Environment Editor.

10.1.3. Changing the Resolution of a Peak

If a peak has a large neighbouring peak in the mass above or below it then you may wish to increase the resolution.

If a peak is small then you may be able to increase the sensitivity by decreasing the resolution, provided that there are no neighbouring peaks that might interfere.

There are two variables that control resolution : **delta-m** and **resolution**. **delta-m** has most affect at low masses, **resolution** at higher masses. Both devices have an arbitrary operational range of +/- 100%.

10.1.4. Reducing the size of a large peak.

If a peak has a signal greater than 500,000 c/s then it is strongly recommended that the signal be reduced to avoid damaging the SEM. The working life of the SEM is determined by the total number of ions that it exposed to., if the signal is greater than 200,000 c/s then decreasing the signal will increase the life of the SEM.

There are three ways to reduce the size of a peak

1. Increase the resolution – see section X.1.3
2. Use a different ion.
3. De-tune an Analyser Control variable.

Never decrease the signal by reducing the multiplier voltage. The signal will be reduced by decreasing the multiplier voltage but this does not decrease the number of ions so it does not increase the multiplier life. The multiplier should always be operated at the correct voltage, as described in section 4.x

10.1.4.1. Using a Different Ion

The signal may be reduced by choosing a different ion generated by the layer.

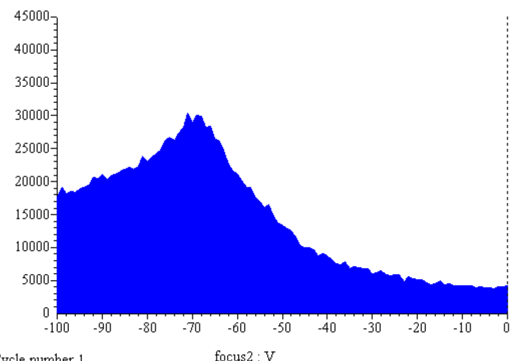
For substrates choose a fragment ion instead of the major peak:
Instead of Al from Al2O3 at mass 27 use AlO at mass 43
Instead of Al from AlTiC at mass 27 use Ti at mass 48. The Ti^{49} isotope at mass 49 will give an even smaller peak.
Instead of Si from SiO2 at mass 28 use the SiO peak at mass 44

For elements choose a different isotope:
For example the Fe^{54} peak is 6.5% of the Fe^{56} peak.

For mixed layers choose the ion that gives the least signal.

10.1.4.2. De-tuning the Analyser

The signal may be reduced by de-tuning the analyser. The best lens to de-tune is **focus2** because it has a gentle slope. The characteristic curve of **focus2** in SIMS mode may be seen in a Postune file.



To decrease the signal increase **focus2** away from its maximum towards 0V

10.1.5. Importing Tuned Values to a Local Environment

If a layer has a very small signal it may be necessary to optimise the tuning for a particular element. This can be done by running an auto-tune on the element, instead of on Cu. See section 5, Tuning.

At the end of the AutoTune procedure you are given the option to save a Tune file. This Tune file may be imported into a Local Environment. The values for the tuned variables will be imported into the Scan's Local Environment and will have their "Use" check box checked.

To import a tune file follow these steps:

1. Select the Scan Tree window.
2. Select the scan in the Scan Tree. If the scan already has a Local Environment then select the Local Environment's Set: box.
3. From the Menu Bar select **File, Import, Environment, Tuned Values**. A standard File Open dialog is displayed.
4. Select the .tun file saved by the AutoTune procedure and click on **Open**.
5. A Local Environment will be created and the tuned values will be imported into it.
6. Double click on the Local Environment to inspect the imported values.

7. Only the variables that were tuned will have their “Use” option checked.
8. Close the Local Environment Editor by clicking on **OK**
9. Save the file using **File, Save** from the Menu Bar.

Once a Local Environment has been imported to a scan it may be Copied and Pasted into other scans in the same file, or between files.

A Local Environment may be deleted, by selecting its Set: box in the scan tree and using the delete tool. , or by using the Del or Delete key. Deleting a local environment does not cause all the views to be closed.

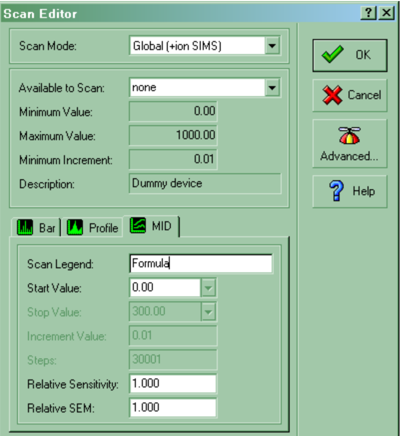
10.2. Endpointing Using Formulae

To endpoint using a formula an extra scan with an f(x) input must be added to the scan tree. The f(x) input is used to calculate a formula, such as a ratio, which is then shown in the Trend View along with the other data. The result of this formula can then be used to endpoint in the normal way by specifying the formula scan as the endpoint-scan.

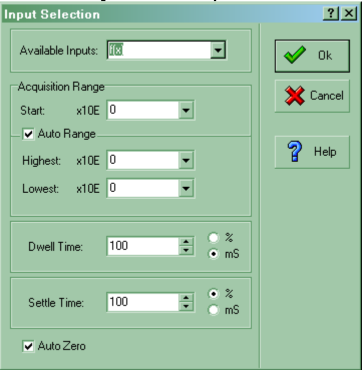
10.2.1. Adding the Formula Scan

1. Open the Template file using the **File, Open** command from the Menu Bar or by using the File Explorer.
2. Select the Scan Tree window.
3. Select the last **Scan** box in the scan tree, by clicking on it.
4. Select the Tool Bar **Next scan** tool . A new **Scan** is added to the scan tree.
5. Double-click on the chosen **Scan** box. The **Scan Editor** dialogue box is invoked.

6. Select the MID (Multiple Ion Detection) tab.
7. In the **Available to scan** drop down list select **none**.
8. Change the **Start Value** to 0 (zero).
9. Enter a meaningful name that describes the function of the formula into the **Scan Legend**.



10. The dialog should resemble this. Press **OK** to close the Scan Editor.
11. Now double-click on the scan's input box (labelled SEM).
12. Select **f(x)** from the **Available Inputs** drop down list.



13. Click **OK** to close the dialog

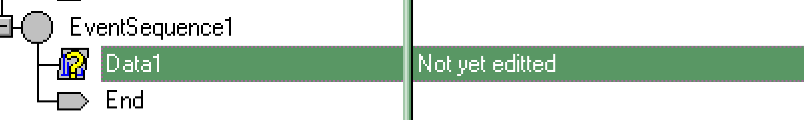
10.2.2. Calculating the Formula

The formula is calculated by an Event Sequence. For more information on Event Sequences see the event Sequence Manual HA-085-660.

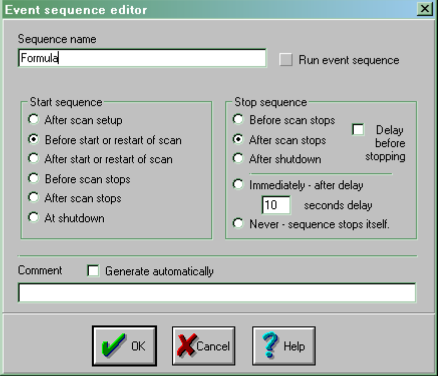
To create a simple Event Sequence to calculate the ratio of two values perform the following steps.

1. Double click on the **Events** box in the Scan Tree.
2. This will display the Event Editor view.
3. Select Events at the top of the window.

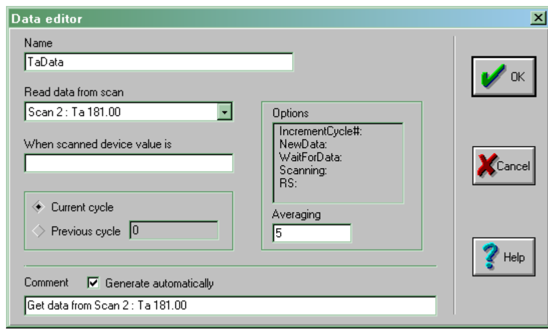
4. Using the right mouse button bring up the pop-up menu and select **Data event.**
5. This will create a new event sequence at the bottom of the view:



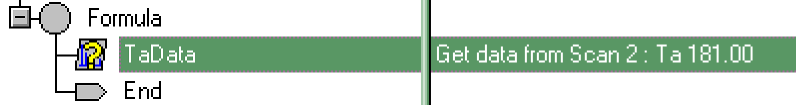
6. Give the Event Sequence a name by double clicking on EventSequence1, the Event Sequence editor dialog will be displayed:



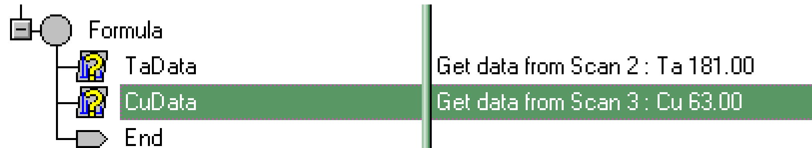
7. Enter the name into Sequence name and press OK to close the dialog.
8. Double click on the Data event.



9. In the drop down list **Read data from scan** select a scan. This Data event will retrieve the latest reading from this scan. The value can then be used in the endpoint formula. You may want to average the data from more than one cycle, this can be done by entering the number of cycles into **Averaging**. Give the Data Event a meaningful name then click on **OK** to close the dialog.
10. The Event sequence should now resemble this.

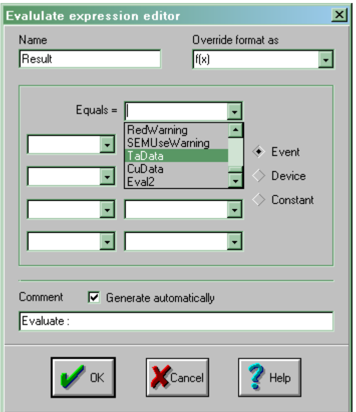


11. With the Data Event selected, as shown above, using the right mouse button add another Data Event. Edit this to get data from another scan. You should now have two Data Events in your event sequence:



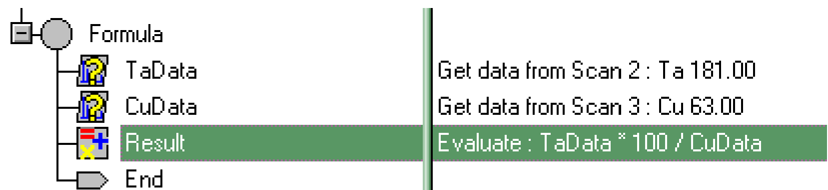
12. Now add an Evaluate event. Call the Evaluate event Result. A simple formula may be enterered into an Evalauate event. This example expresses the Ta signal as a percentage of the Cu signal.

- Change the name to Result.
- Select f(x) in the **Overide format as** drop-down list.
- Select the edit box to the right of **Equals =**
- Select the **Event** radio button.
- Select the first Data event, as shown. This will be at the end of the drop down list.

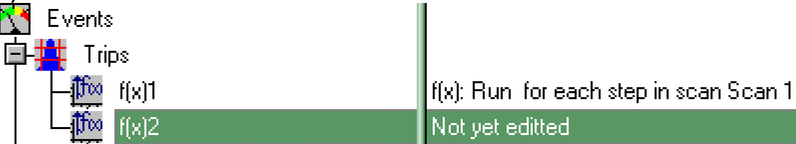


- Move to the edit box below and to the left and select an operator. Valid operators are + - * (multiply) / (divide) Power Root Log Invlog Min and Max. See the Event Sequence User manual for more information.
- Select the operator * then move to the right hand edit box.
- Select the Constant radio button and type 100 into the edit box.
- Move to the next row and select the operator / . Select the right hand edit box.
- Select the Event radio button then select the other Data event as the source.
- The comment is automatically generated. It should an expression similar to:
- Evaluate : TaData * 100 / CuData
- The expression is evaluated left to right without any operator precedence.

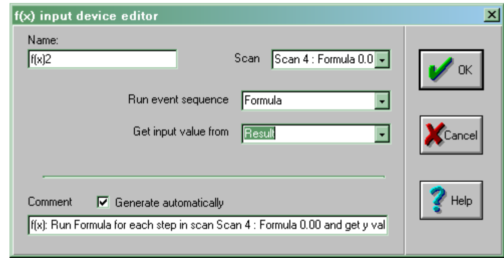
13. Click OK to close the Evaluate Expression editor.
14. The sequence to evaluate the formula is now complete. It should resemble this:



15. The next step is to associate the event sequence with the f(x) scan in the scan tree. This tells the scan which sequence to run to calculate the formula and where to get the result from. To do this add an **f(x) input device** to the Event Sequence using the right mouse button pop-up menu. The f(x)2 will be added at the top of the Event Sequence window after f(x)1; f(x)1 is used to draw the Chart Mark.



16. Double click on f(x)2 to open the f(x) input device editor.



17. In the **Scan** select the scan that has the f(x) input

18. In **Run event sequence** select the name of the sequence that you created in step 8; in this example this is Formula.

19. In **Get input value from** select the Evaluate result that hold the result; in this example this is Result.

20. Click **OK** to close the f(X) input device editor dialog.

10.2.3. Setting the Endpoint Variables

1. Select the Scan Tree window.
2. Double click on the Global Environment box to open the Global Environment Editor.
3. Set the **endpoint-scan** to the scan number of the scan with the f(x) input.

4. Set the **reference-scan** to 0.

5. Set the **method** in the normal way, Use method 1 for the rising edge of the value calculated by the Formula, use method 5 for the falling edge.
6. Layer counting may be used if required by setting the **endpoint-layer** and using the appropriate method.
7. The **limit** and **slope** will apply to the value calculated by the formula. Their value can be found by running the template on a test wafer with the **initial-delay** set to a large value to prevent endpoint being found, see section 8.5. To see the data you may wish to create a separate view of the f(x) scan because it will share the Y axis with the chart mark.
8. **RPM** and **symmetry** have no affect when using the f(x) input; the dwell time for data acquisition is set in the scans specified in the Data events.
9. The remaining endpoint variables function normally.

10.2.4. Running the Template

Add Views to the scan (see section 8.4.3).
Save the file **use File, Save** from the Menu Bar.
Close the file.
Create a Script Interpreter script in the normal way, see section 8.7
The template is now ready to be used.

10.3. Improving the IMP performance

Typical methods of optimising the sensitivity to get the most out of the IMP include:
• If the system has not been optimised in SIMS mode for a long time, tuning the system, as described in Section 7, may increase the signal intensity.
• When monitoring masses, which have no signal in adjacent mass channels, use a local environment file to set the **delta-m** parameter more negative just for this mass. This will increase its intensity and, as there are no signals either side of it, will not result in 'tailing' into the adjacent mass channel. (Tailing is where the bottom part of a mass peak overlaps into the next mass channel.)
• Tailing can sometimes be seen when monitoring many ions of a similar mass, for example Cr at 52 amu, Mn at 55 amu, Fe at 56 amu, Ni at 58 amu and Co at 59 amu. If tailing appears to be a problem in the data, try setting **delta-m** positive to make the peaks narrower.
• If the signal intensity is too high for a peak (often seen on Al from Al_2O_3 substrates) the SEM signal may saturate at about $5x10_6$ c/s. Again, use a local environment to reduce the signal as follows:
– Set the **delta-m** parameter to a more positive value (0 % is the normal value, 100 % the maximum), or set a focus plate less negaive.
– Don't reduce the **multiplier** voltage to try and reduce the count rate.
• Dwell times can be critical for the appearance of IMP data; they usually need to be increased from the default setting of 100 %. Shorter dwell times usually mean noisier

data, which can affect endpoint detection. Each application may require a different dwell time. Things to take into account when setting dwell time are:
– The number of masses that need to be monitored.
– The approximate time it will take to endpoint.
– The width of the layer it is end pointing on.
For a very thin layer with a very long dwell time, it is possible that the etch could go through the layer without the EPD acquiring enough data points to satisfy the endpoint criteria and the endpoint may not be found. Typically, dwell times are set between 200 and 700 ms. The dwell times of the masses not used for endpointing are not critical and may be shorter than that used in Scan 1.
• The sample rotation will be seen in the acquired data, but should not cause a problem in finding the endpoint. However, the effect of the rotation can be removed to a certain extent by setting the dwell time to match the period of the rotation. If the rotation speed is r revolutions per minute and the wafer has Cn symmetry, then the dwell time should be:

$$\frac{60000}{r.n}$$

• It is better to monitor fewer masses with longer dwell times, than to monitor every element on the wafer with very fast dwell times. Often scans are generated that use more than one mass to represent each layer. Using a high signal, with low background noise, select only one mass to represent each layer and then increase the dwell times on this mass.

11. Troubleshooting

11.1.Factors affecting peak height

The peak height is affected by :

- The etch rate - the faster you etch the bigger the signal - low etch rate, low signal
- The amount of mask - a 98% masked wafer will have 1/5 of the signal of a 90% masked wafer
- The metal being etched. The EPD is more sensitive to some metals than others.
- The EPD file settings. The EPD “template” file has to be “tuned”. The tuning is affected by things like the plasma power, the angle of the stage, and the metal being etched. Therefore every type of wafer needs its own “template” file.

11.2.Endpoint detection problems

- If the EPD does not tell the EPM to stop then etching will continue until the step time in the EPM recipe is reached.
- If this happens the EPM can be made to stop, display a message, and not process any more wafers. This is done in the EPM not the Hiden EPD.
- If the EPD fails to find an endpoint then you, or a process engineer, should find out why before etching any more wafers.
- The log file can tell you if the Hiden EPD found the endpoint
- Sometimes the Hiden EPD can find the end of the last peak but the EPM stops the etch before the overetch time has elapsed. You can tell if this has happened by looking at the log on the Hiden EPD. If this is happening you should probably increase the step time in the EPM

11.3.Etch problems

Problems with the etch that can cause endpoint not to be found

- Etch rate too slow - EPM end etch before Hiden EPD finds endpoint
- Step time in EPM recipe too short.
- Layer not deposited
- No wafer
- Wrong type of wafer
- Right wafer stack , different mask

- Plasma beam not stable
- Shutter closed
- PBN not operating correctly
- Wrong etch angle, signal too small.

11.4.EPD problems – no endpoint.

Problems with the Hiden EPD that can cause endpoint not to be found

- Orifice blocked
- Baffle bent
- SIMs unit switched off
- Signal too small due to loss of detector sensitivity (multiplier voltage too low)
- Hiden EPD not tuned properly
- Wrong endpoint settings in template file

11.5.EPD problems – wont run.

Problems that prevent the Hiden EPD running at all

- MSIU switched off
- Fault LED on MSIU comes on.
- MASsoft not running
- Script Interpreter not running
- Pressure too high in EPD analyser
- External trip cable to the MSIU is disconnected
- Error in EPM recipe - The script name in the etch recipe is wrong.
- The etch step number in the script file does not match the step number in the EPM recipe.

11.6.EPD problems - no peaks

The following things could cause complete loss of signal - no peaks:

- Orifice blocked
- Baffle bent
- SIMS unit switched off (no signal at all for any metal)
- The detector operating (multiplier) voltage set to 0.
- A cable is disconnected. Especially pulse counter signal cable.
- RF Head not fully pushed home on flange connector.
- No plasma beam
- Shutter closed

11.7.EPD problems - small peaks

The following things could cause the signal to be too small:

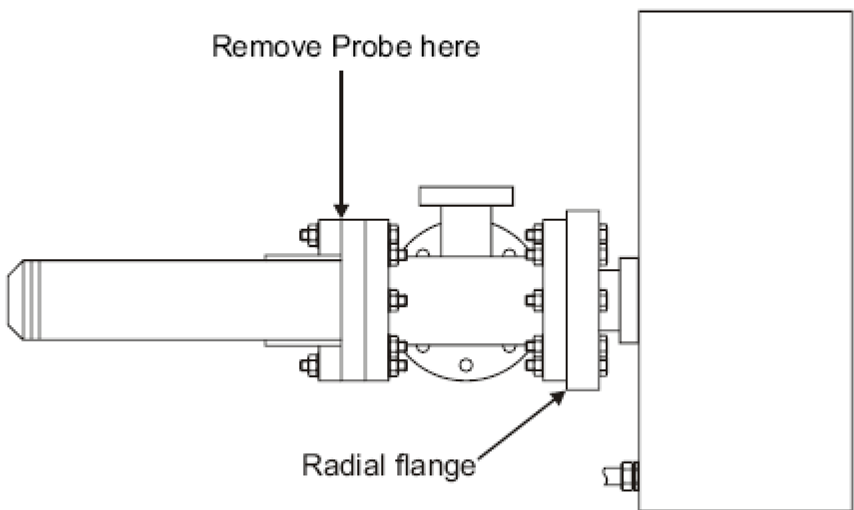
- Orifice partially blocked
- Baffle bent
- The detector operating voltage needs increasing. The multiplier voltage in the template file needs setting.
- The template file needs tuning.
- The etch rate is slower than usual
- The wafer is more highly masked than usual.
- The etch angle is more acute.

12. Preventive maintenance

WARNING
The following procedures must be performed by suitably qualified personnel with experience of vacuum systems and high-voltage circuitry.

12.1. Removing the Probe from the tool chamber

If it is necessary to remove the Probe from the tool chamber, remove the RF Head and remove from the chamber flange at the point shown in Figure 9. Withdraw the Probe carefully. See Manual number HA-085-019, “Ion Milling Probes Operator’s Manual” for more information on Probe handling.



Note:
Although the bare gauge can be removed from the system at the radial flange, Hiden do not recommend this procedure as refitting it to this configuration can result in pressure on the mass filter. This can twist the stack and mass filter and result in deterioration in the gauge performance. Contact Hiden Analytical Limited if further information is required.

12.2. Checking the Probe for Shorts

The probe is mounted on the chamber door. If the probe suffers an impact due to the door swinging against an obstacle it may suffer internal damage to insulating ceramics, this may result in a short circuit.

Internal deposition of metal or metal flakes may cause short circuits during use.

Short circuits may occur in-transit due to screws loosened by vibration.

Whenever fitting or re-fitting the Ion Milling Probe to the main chamber it is important that the probe is checked for short-circuits.

The base flange consists of a 12-way feedthrough and five radial connections.

For the IMP, pins 3, 6 and 9 should be connected to each other but not to ground. All of the other pins should be open circuit to each other and to ground. Pin 1 is ground.

It is also important to make sure that the five radial MHV connections are also open circuit to each other and the 12 pins on the feedthrough.

Check each pin in turn 1 to 2 …11 and to radials 1 , 3, 4, 7 & 8.
then 2 to 3 …11 and to radials 1 , 3, 4, 7 & 8.
and so on systematically, ending on radial 7 to radial 8.

The insulating ceramics on the radial MHV connectors should be inspected for cracks and signs of arcing.

Figure ? below shows the location of the pins and radials on a 5-way IMP baseflange.

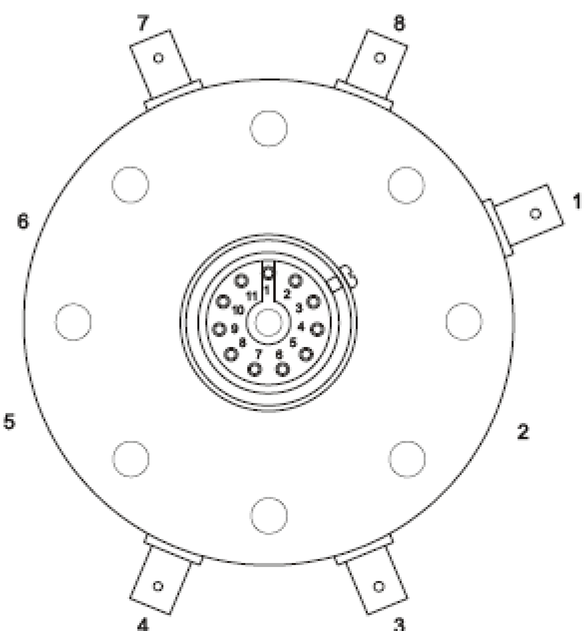


Figure ? – Probe 12 way feedthrough and radial MHV connections

If any pins are short-circuited, with the exception of pins 3, 6 and 9, please contact Hiden Analytical.

12.3.Checks during Tool PM

12.3.1.Introduction

The following EPD maintenance operations should be carried out during tool PM checks, if any problems are experienced with the System or if the end point does not finish correctly. If any problems are found, email the five test result files (see Section 11.2.4.1)
to Hiden Analytical Limited, along with the system's serial numbers (for all components), System history and any other relevant information.

Material deposited on probe.

Preventative Maintenance

1. Remove any deposited material from the end of the probe
2. Check the mass alignment
3. Check the Secondary Electron Multiplier (SEM) detector
4. Archive the event log

12.3.2. General maintenance

1. Check that all the cables connecting the EPD components are in good condition and are securely connected
2. When the tool chamber is open for maintenance, carefully clean the outside and front of the EPD Probe.

Clean away any sputtered material, taking extreme care that no debris falls into the sampling orifice

3. Check the sampling orifice to ensure it is not blocked by debris
4. Clean the inside of the chamber — The front of the EPD Probe should be covered to protect it from sputtered material.
5. Check the PC file systems: remove, or archive, any redundant EPD files.

12.3.3. EPD testing; running the PM test file

The PM Test file should be run after tool maintenance is complete and the chamber is being pumped down. The file checks the response profile of all the EPD variables and the SEM detector. Data collected during the run should not be stored in the original file as this contains known good data acquired when the Probe was first delivered. When the run is complete, the EPD condition may be evaluated by comparing the profiles with those in the original **pm_test** file.

The **pm_test.exp** file should be run at least once a month to check the SEM detector and mass alignment.

See section 4

12.4. Further checks

These should be performed every 3/6 months

1. Check the EPD tuning
2. Check the system safety

13. Maintaining system safety

The following points should be checked every two years in order to maintain safe operation of the equipment.

Remainder as **Serial End Point Detector 55 Document Number: HA-085-064**

Appendix A