IMP EPD – End Point Detector

An overview of the Hiden Analytical SIMS end point detector system for ion beam etch applications

IMP-EPD Presentation Topics

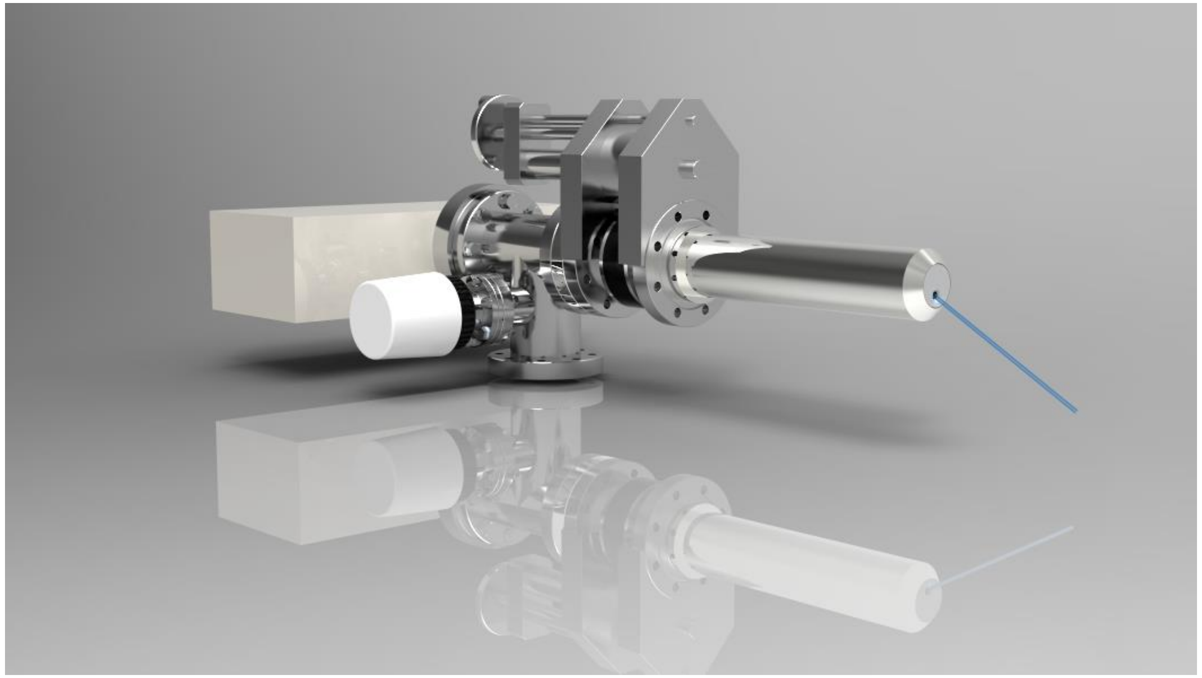
The topics covered in the presentation include:

- A description of the Hiden IMP end point detector system
- Example data
- Hardware and software Integration with process tools

Hiden IMP EPD

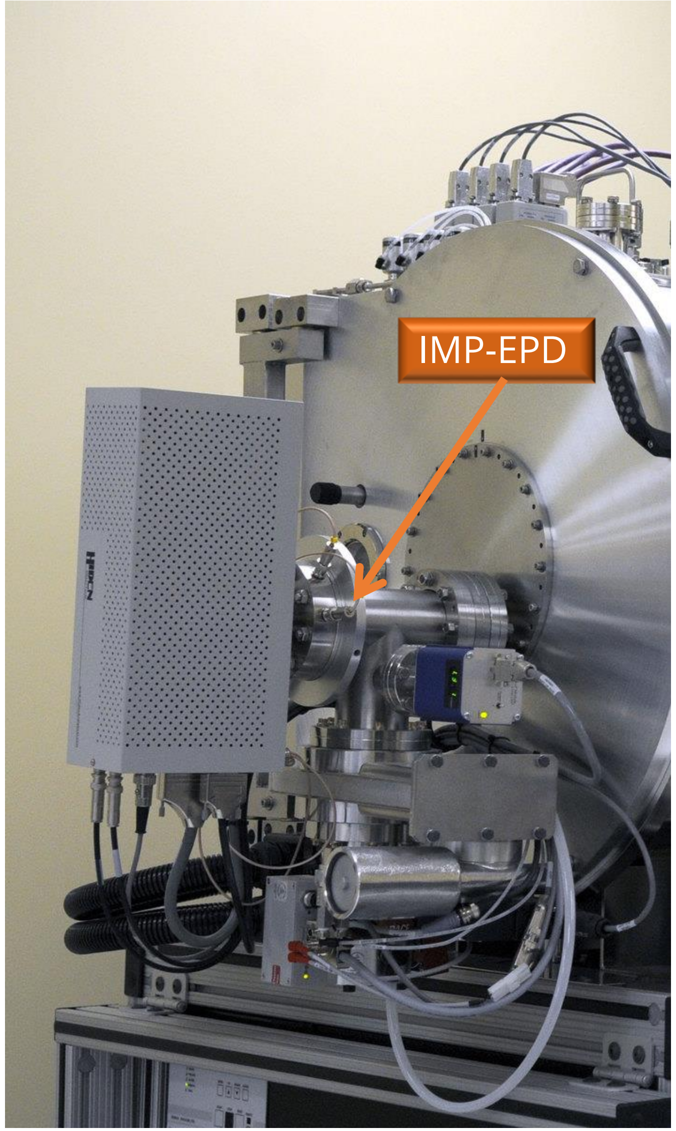
The Hiden IMP EPD is used for the precise end point detection in the ion beam etch step of the fabrication of thin film devices

The Hiden IMP is a differentially pumped, ruggedized secondary ion mass spectrometer for the analysis of secondary ions and neutrals from the ion beam etch process



The IMP EPD system comprises:

- Stainless Steel Shroud with Sampling Orifice
- Ion Optics with Energy Analyser and integral ioniser
- Triple filter Quadrupole mass analyser
- Pulse Ion Counting Detector
- Differentially Pumped Manifold With Mounting Flange to Process Chamber
- Data System with integration to the process tool



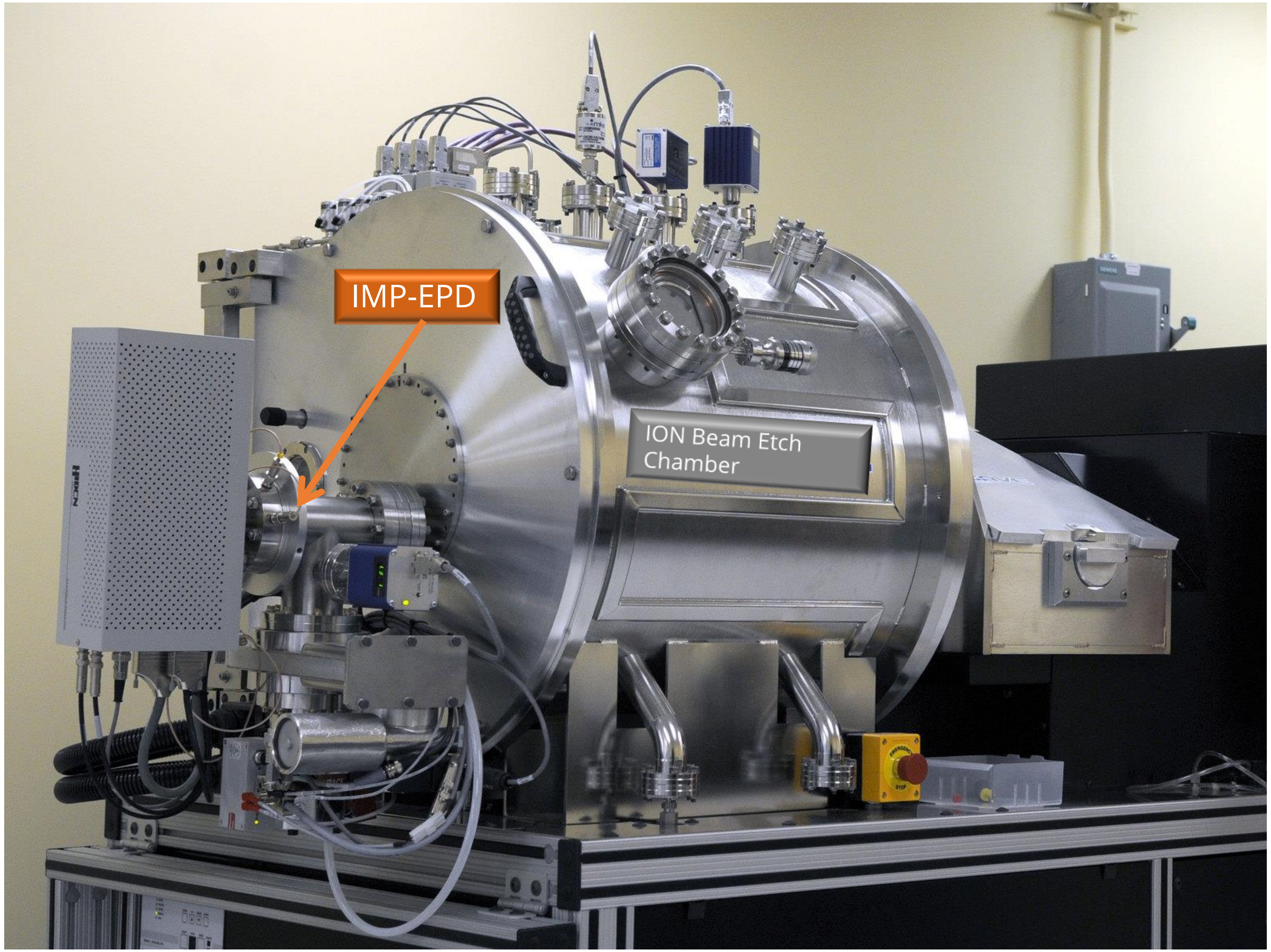
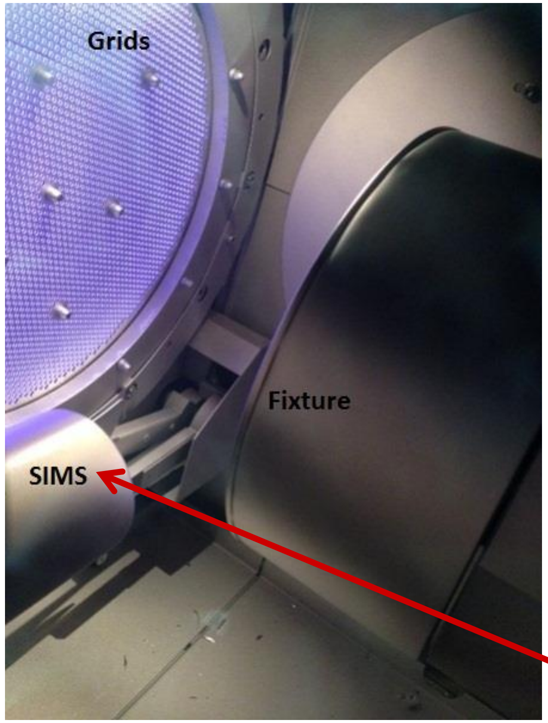
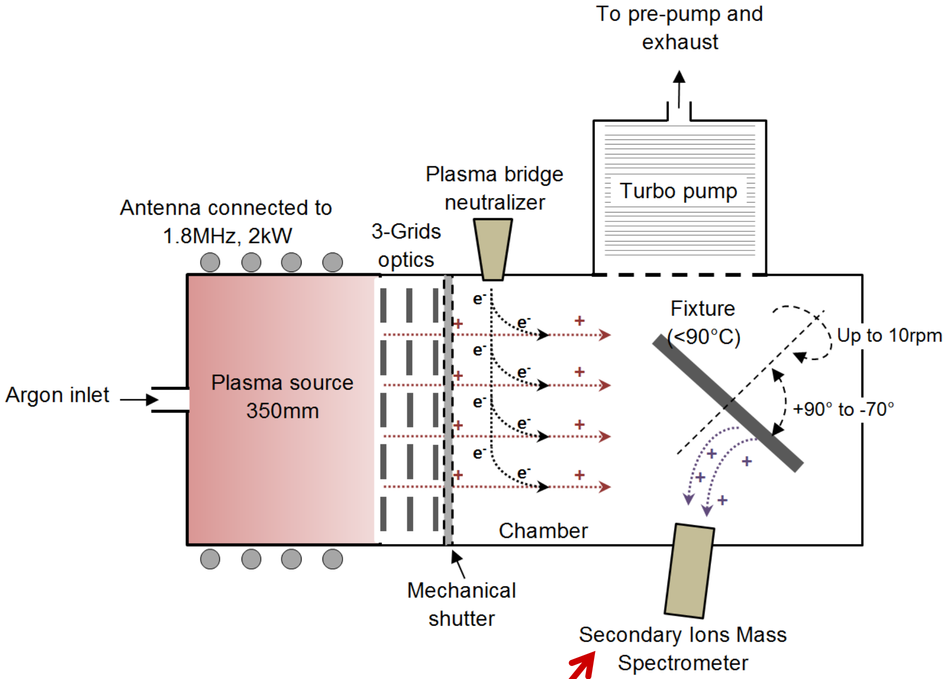


Photo courtesy of: http://www.ifixit.com/Teardown/Apple+A6+Teardown/10528

Inside a typical ion beam etch chamber





IMP- EPD Analyser

Photo and Diagram courtesy of EPFL

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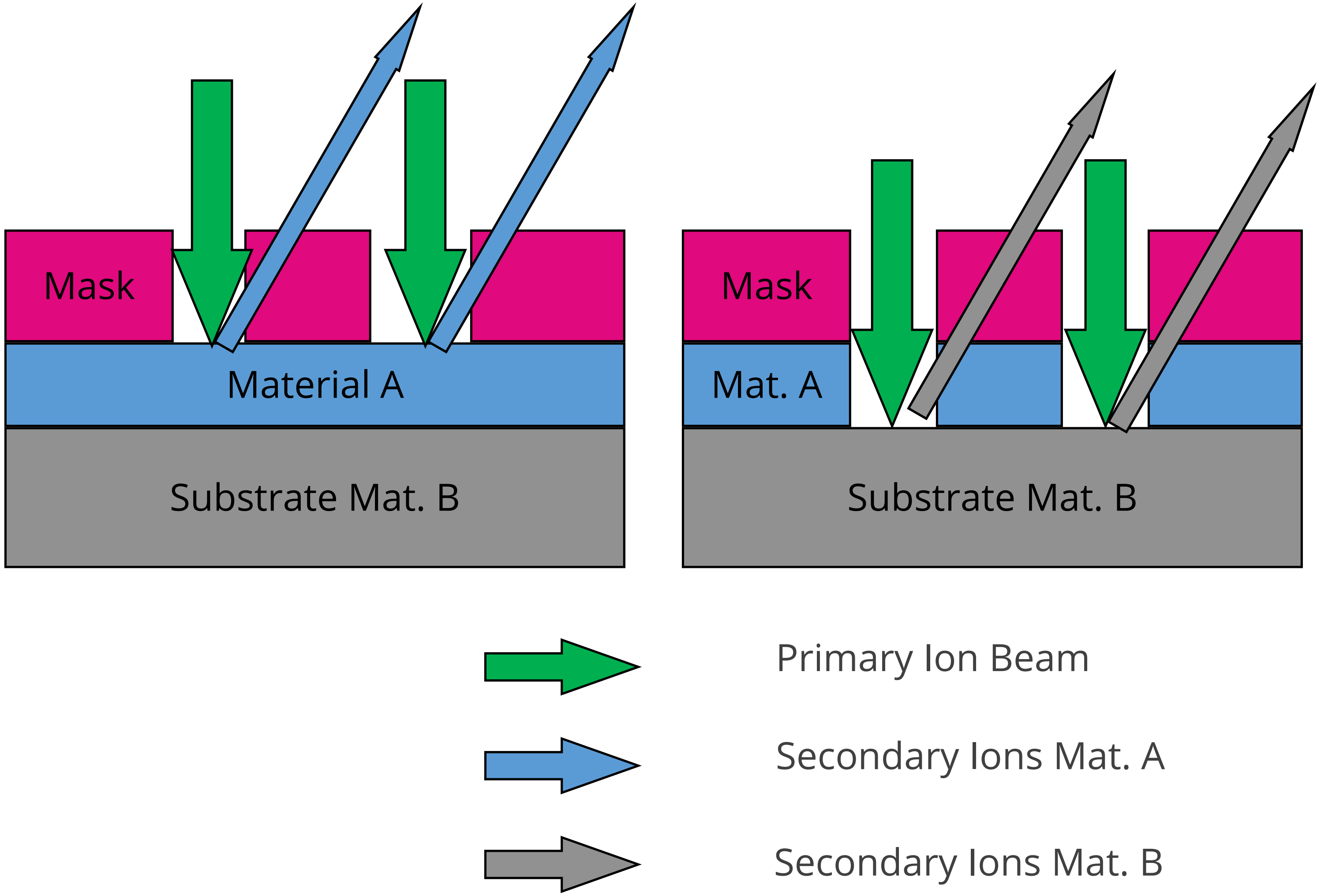
End Point Detection

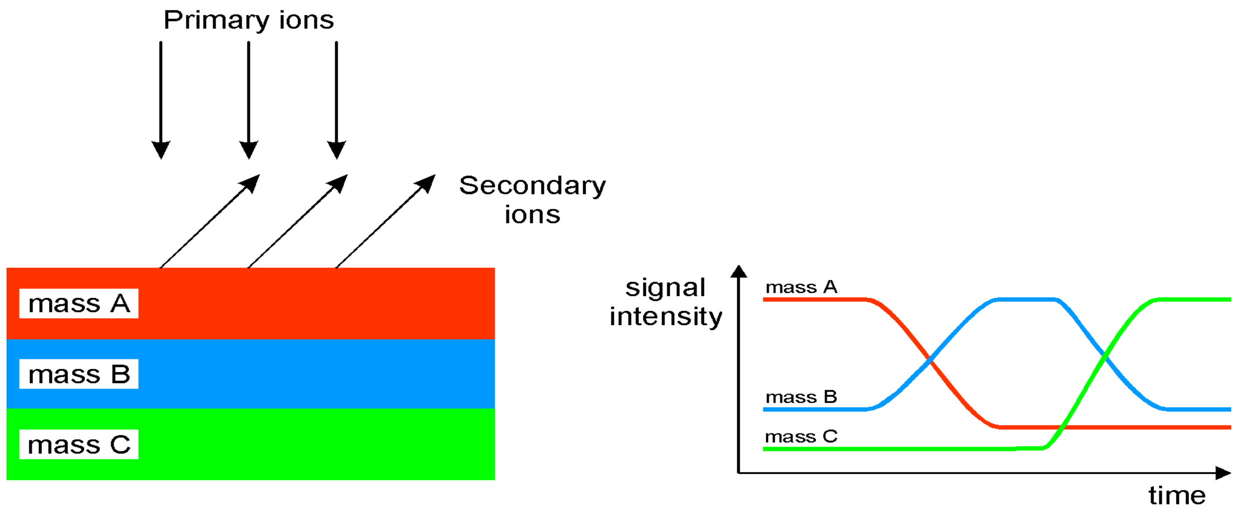


IMP EPD end point data

The data from the IMP end point detector provides a trend analysis for each component of the etch stack. The trend analysis provides a real time display of the entire etch process.

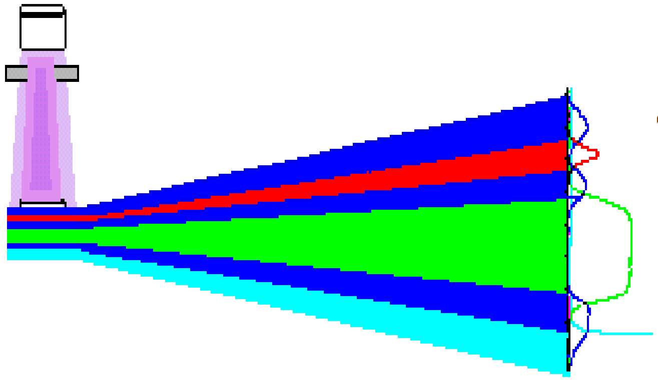
The etch resolution combined with the sensitivity of the SIMS technique provides for end point detection to within **+/- 5Å** .

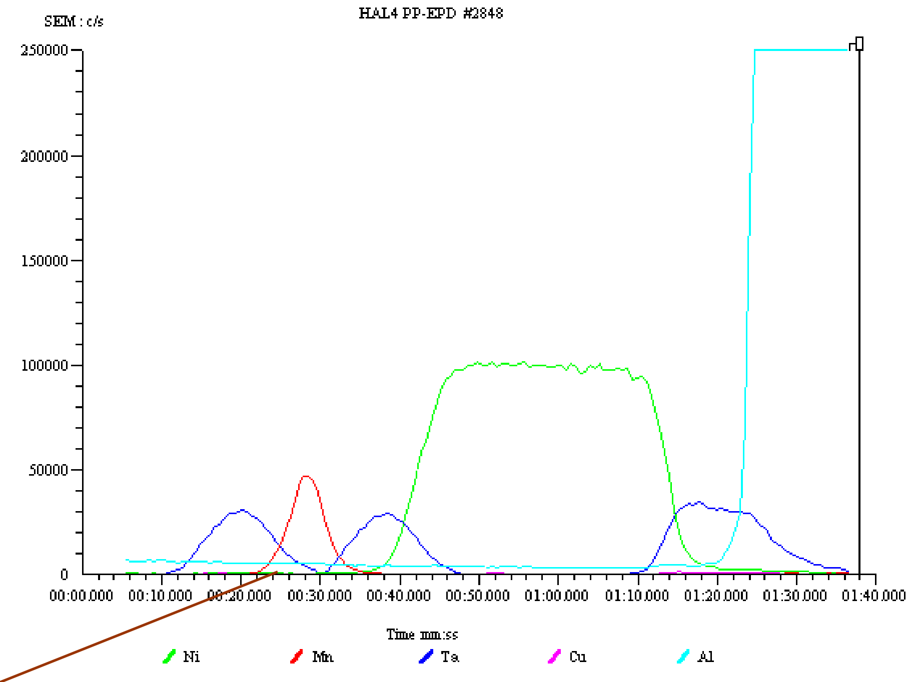
The signals for each layer of the stack materials are coupled with algorithms and data I/O interfaces to provide for automated end point for a broad range of etch end point criteria including rising and falling edge.



Data Output

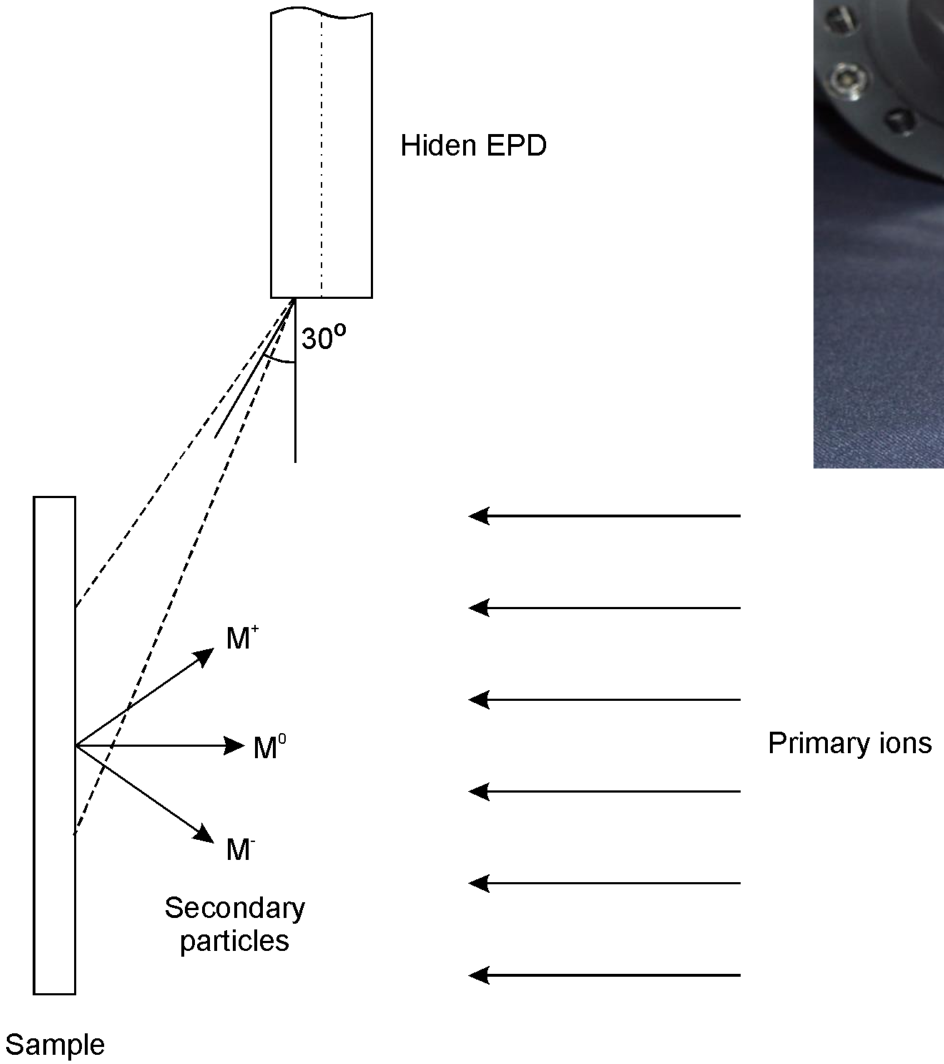
- Each peak corresponds to a layer.
- Each colour corresponds to a metal or other element.

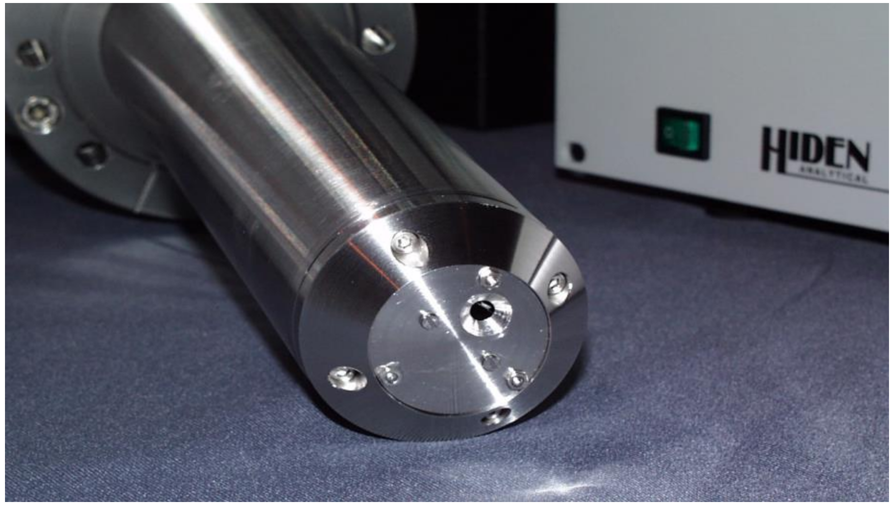




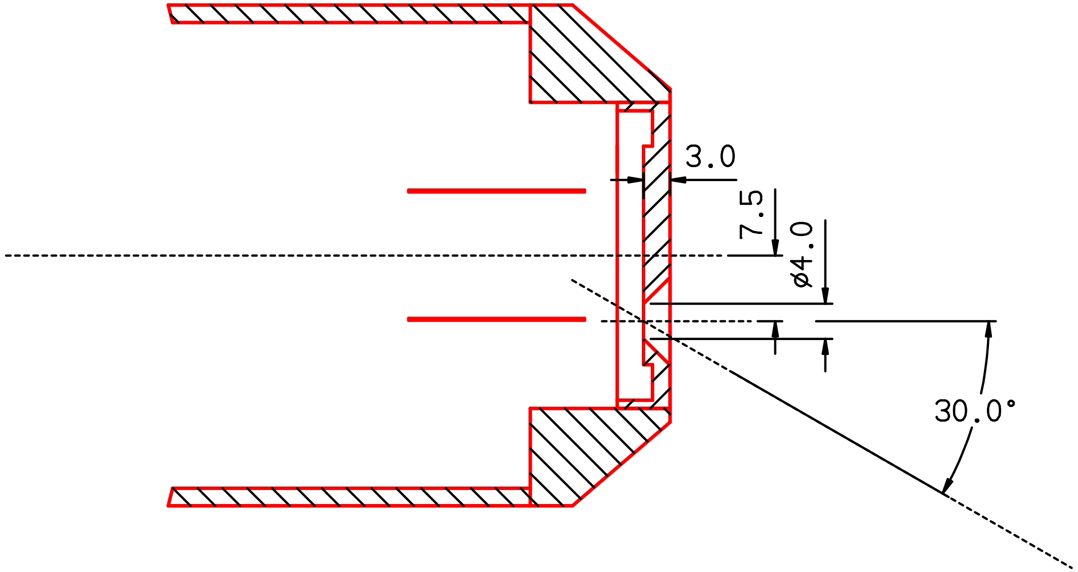
When you etch through a layer the signal goes up.

Signal collection

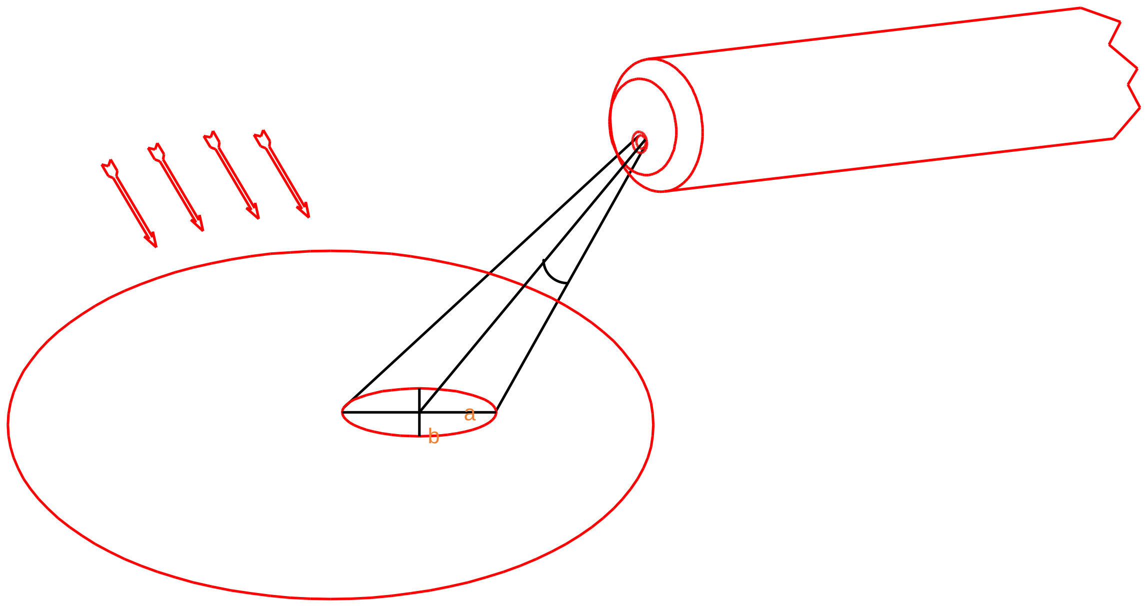


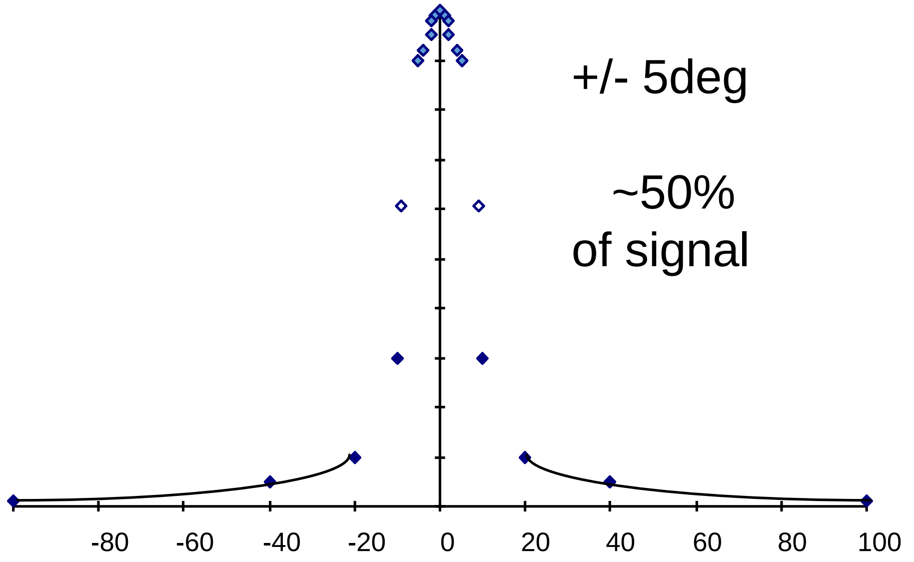


Front end detail



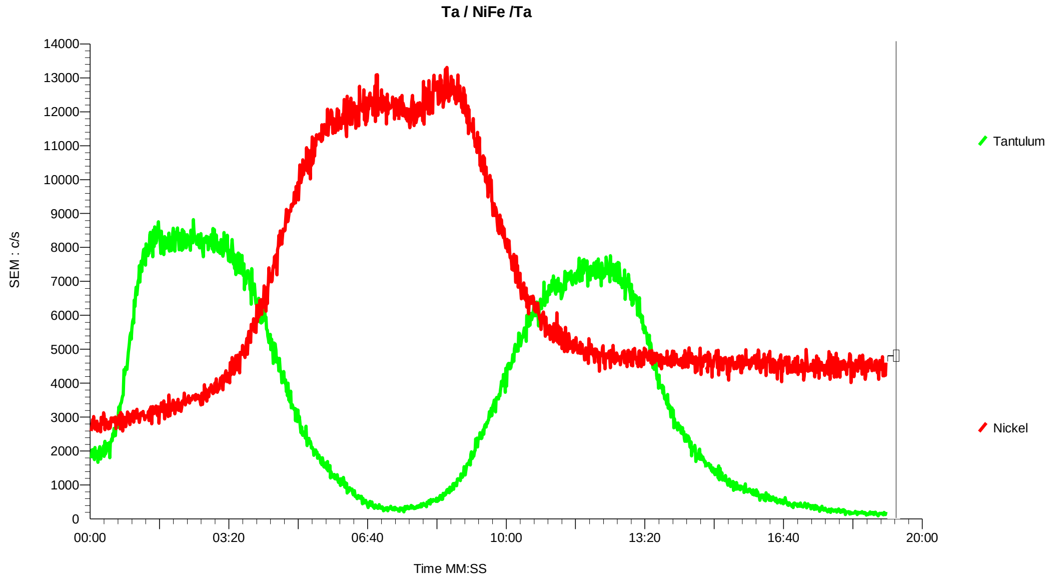
Angle of acceptance





Relative angular acceptance

Example data - 30 Angstrom Tantalum Layers

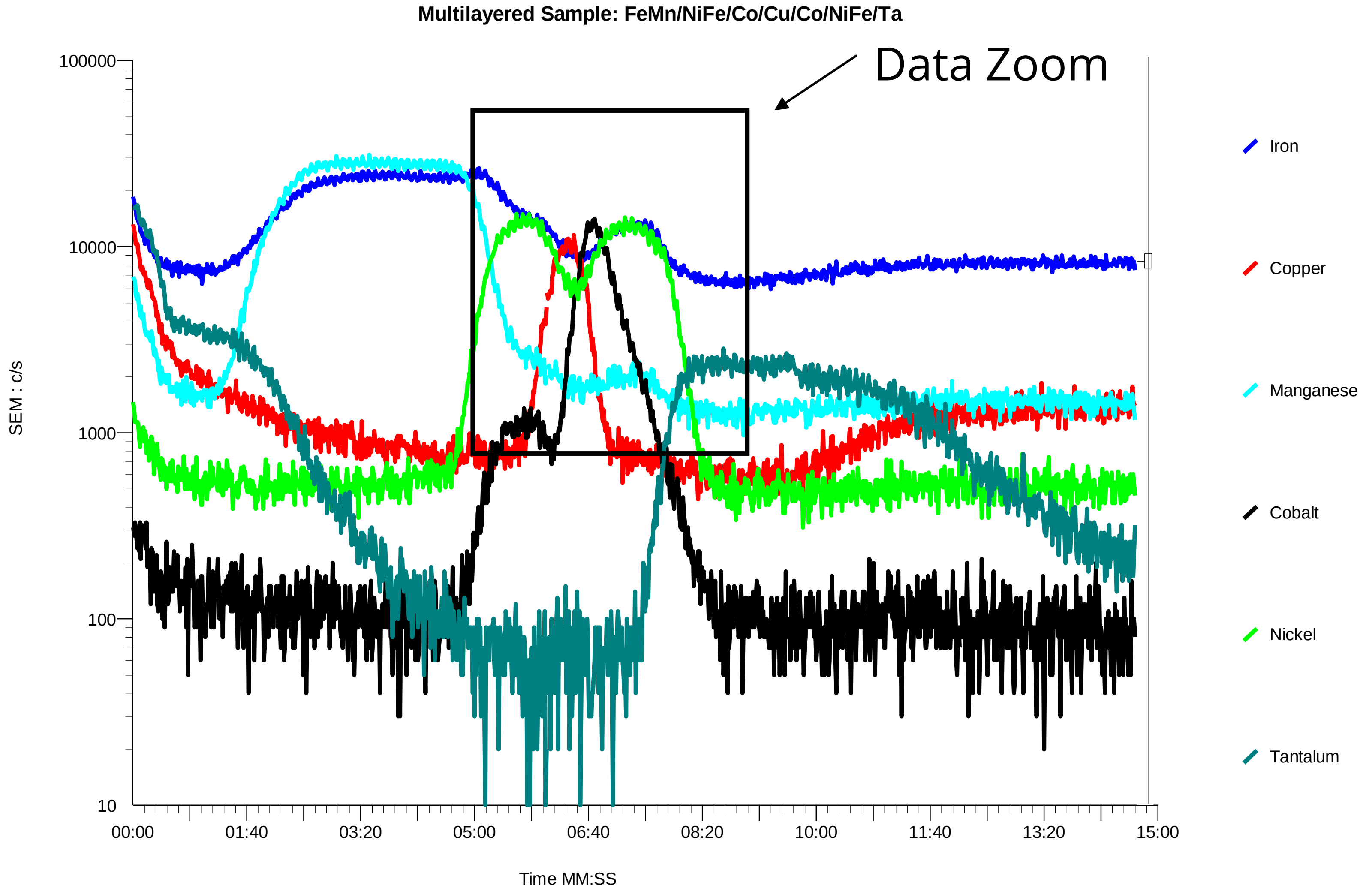


The IMP EPD data shows the depth resolution achieved in an ion mill of a:

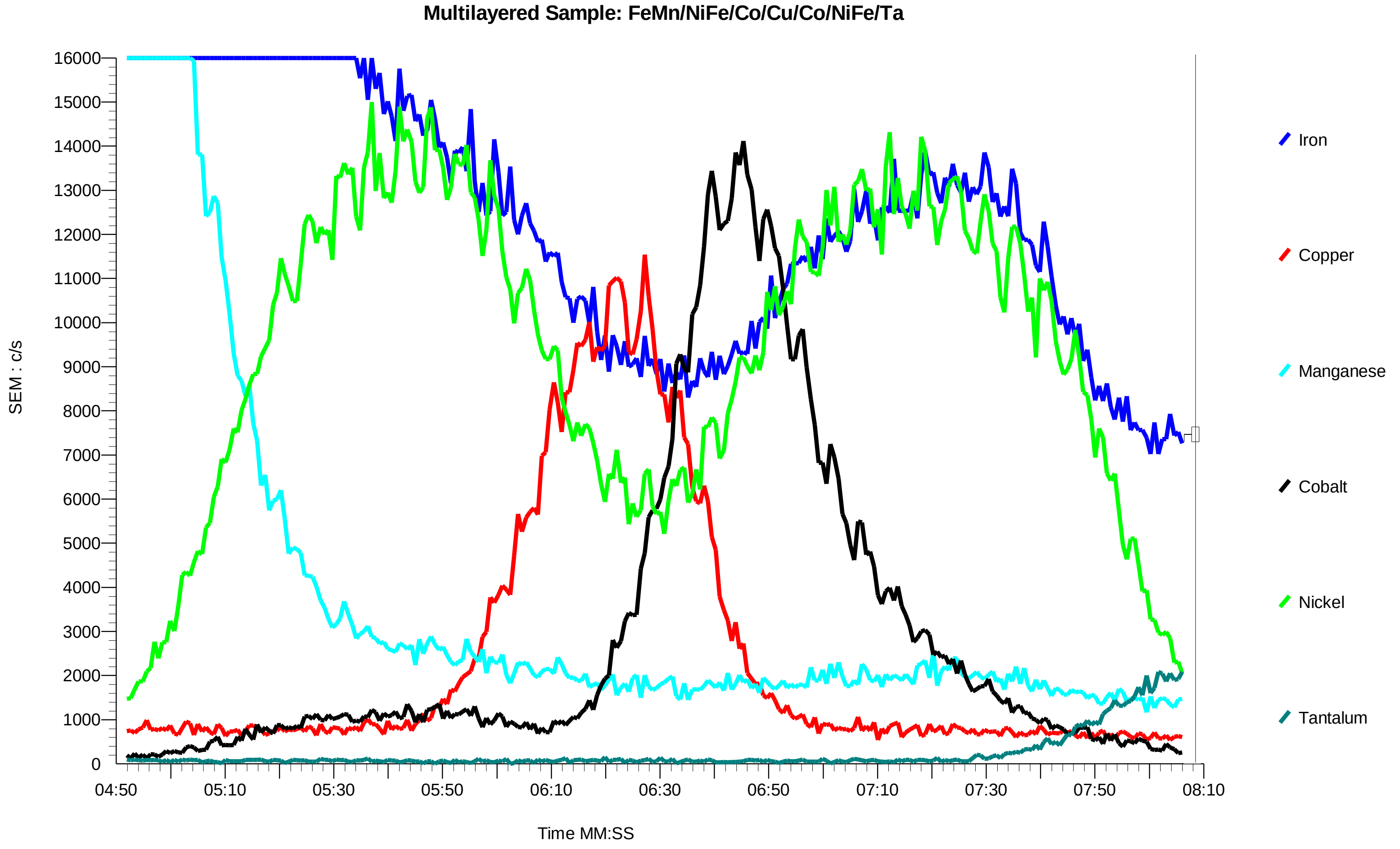
tantalum / nickel iron / tantalum stack

where the tantalum layers are 30 Angstroms.

Example Data



Data Zoom in showing signal variation due to wafer rotation



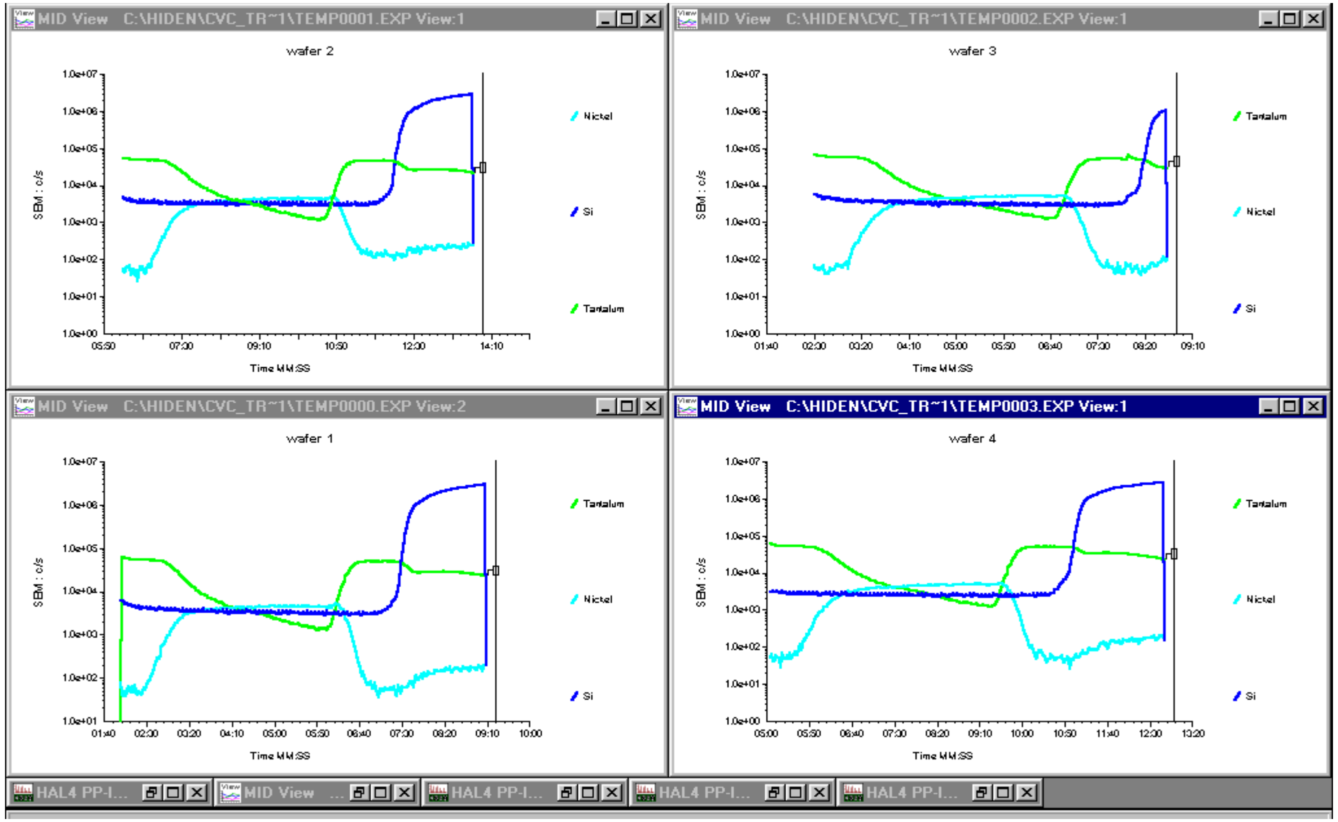
4 Wafers run sequentially:

Wafer number 3 has an imperfection recorded

The data shows the consistency of analysis in production.

Tantalum, Nickel and Silicon are monitored.

The third wafer has an imperfection in the recorded silicon signal.



IMP –EPD Materials Guide-

SIMS analyses all elements dopants and clusters

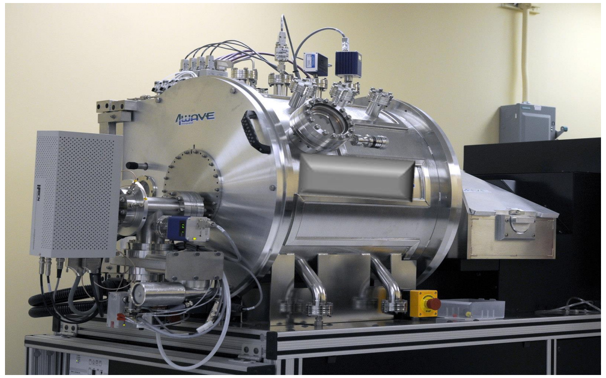
INTERFACE	APPLICATION EXAMPLE
Si/Ga	Identification of SiO_2 interface on III-V semiconductor.
Au/Cr/Al	Au/Cr track identification on aluminium substrates.
Au/Ti/Ga	Precise definition of Au/Ti electrical contacts in GaAs.
Mo/Ge	Precise definition of Mo/Ge interfaces in multifilm Mo/Ge structures.
Al/In	Identification of the interface between two semiconductors Al In As/InP.
Al/Ga	To etch down to the interface between two layers of AlGaAs separated by a 79 Å GaAs well. The Al signal clearly identified the sandwich.
Y/Ba/Cu/MgO	Identification of separate layers in multilayer superconductor materials.
NiCr/Cu/NiFe/SiO2	Magnetic disc sensor head manufacture.

Mass Channels For Layer Materials

Layer	Mass to monitor	Mass number
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

Process Variables that affect angle of acceptance include:

- Wafer tilt – The IMP end point detector probe operates over a wide range of wafer tilt angles
- Surface roughness
- Primary ion beam energy



The sensitivity of the Hiden IMP-EPD is sufficient to provide end point control on 99.9% masked wafers.

End Point Control

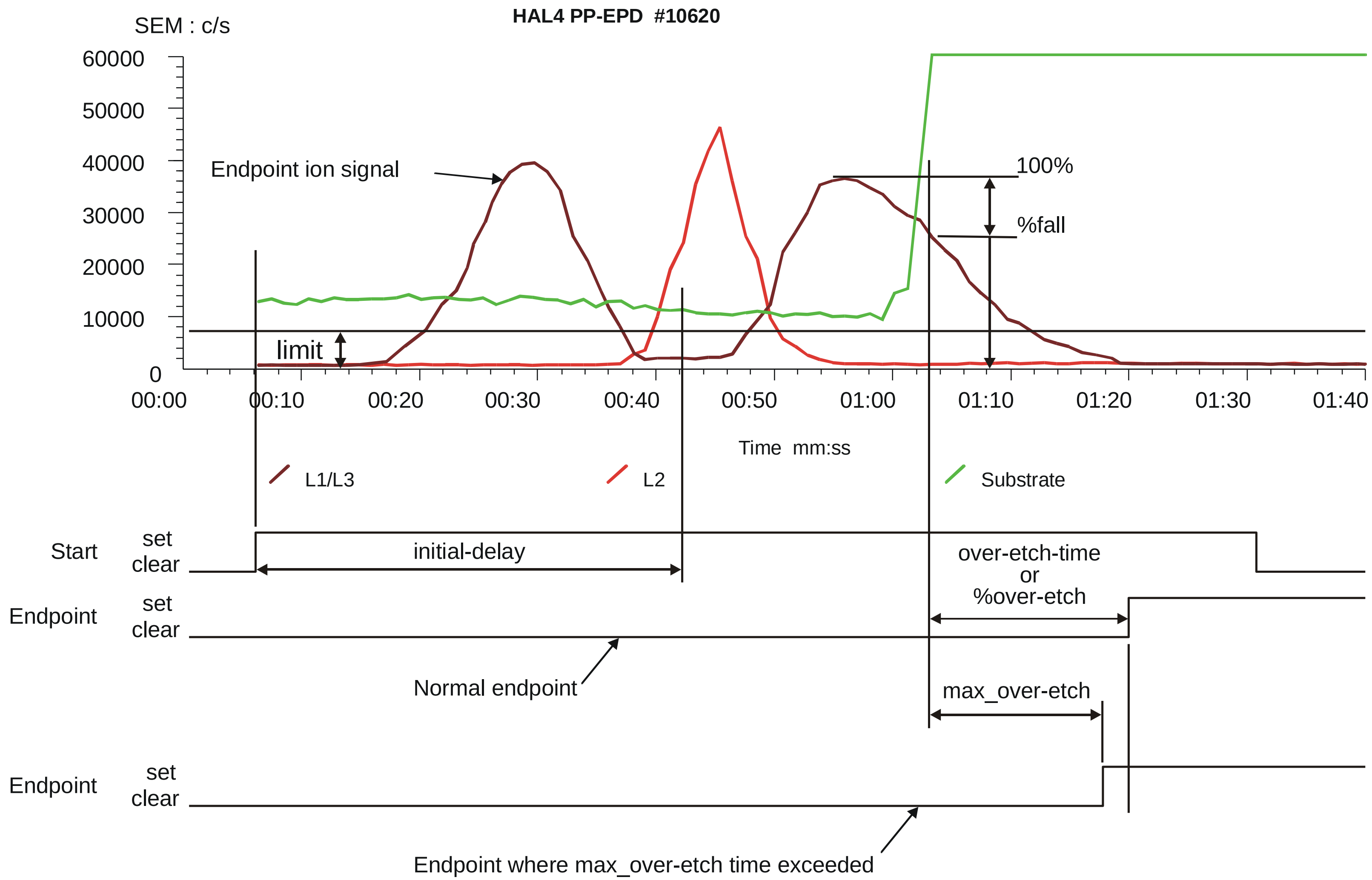
- The end point is controlled with the following criteria:
- Rising edge or Falling edge with variables:
    - Mass channel
    - Percentage over etch
    - Timed over etch
    - Time out over etch

End Point Control Parameters

Endpoint detection is based on a falling or rising trend in the signal; signal intensities and change rates must be entered into the endpoint template for the EPD to operate correctly. Values are needed for the initial delay, slope, limit, falling, % fall, over-etch-time, and % over-etch parameters, which are defined as follows:

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.
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.
over-etch	The time, in seconds, after the endpoint is detected before the endpoint signal is set true. Determines time how long the etc 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	The maximum time, in seconds, that a percentage over-etch may take. This time will not be exceeded etch even if a calculated percentage over-etch time is longer.

IMP EPD end point control



The IMP provides End Point Control-What else does the IMP do?

Target Impurity Determination

- At the start of the etch the ion milling probe provides high sensitivity SIMS spectra for the identification of impurities from surface and primary ion source contamination

Residual Gas Analysis

- The integral electron impact ioniser of the IMP allows for operation as a conventional differentially pumped RGA, with software control for leak detection and gas analysis included

Hiden IMP-EPD users

The IMP EPD was developed in the 1980's for researchers working on new devices based on thin film technology.

The research devices of the 1990's have become full production applications. The 2007 Nobel Prize in Physics was awarded to Albert Fert and Peter Grünberg for the discovery of the Giant magnetoresistance GMR effect.

The IMP-EPD is currently in use 24/7 for production of HDD read/write heads based on GMR technology at Seagate, Western Digital, Toshiba and Hitachi Global Storage.

The IMP-EPD is currently used in the development of the next generation of devices at the worlds leading research centres including:

Summary

IMP –EPD for end point detection in ion beam etch processes:

End Point resolution; +/- 5 Angstroms

Sensitivity sufficient to work with 99.9% masked wafers

Sensitivity sufficient to work with small samples from $6mm^2$ to large scale.

Process control for production

Adaptable to large and small ion beam etch chambers

Operates as a residual gas analyzer, RGA