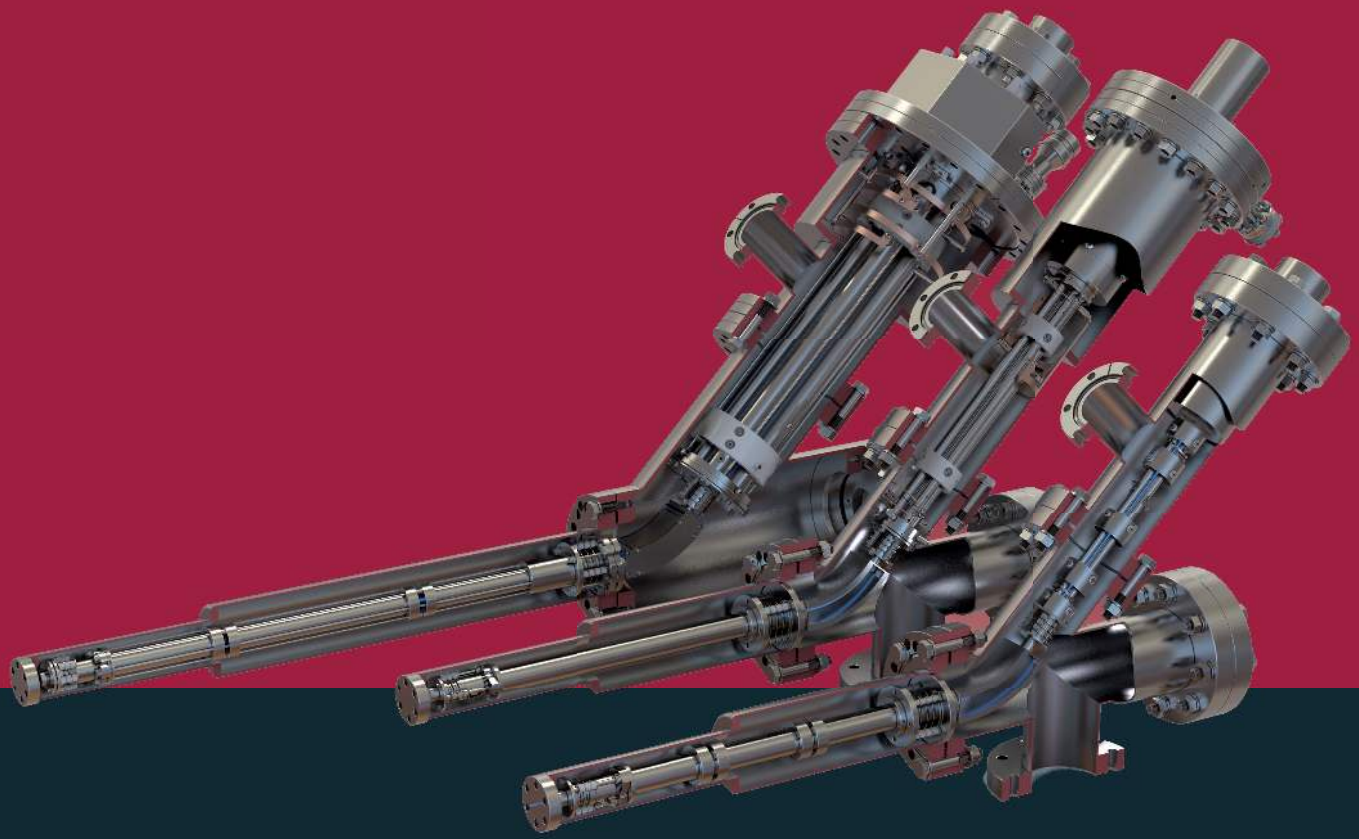
HIDEN ANALYTICAL



EQP Series

- **High Sensitivity Mass and Energy Analysers for Monitoring, Control and Characterisation of Ions, Neutrals and Radicals in Plasma**

The Hiden EQP Series - Mass and Energy Analysers for Plasma Diagnostics and Characterisation

Plasma Sampling Interface

- Plasma is sampled via a **laser drilled orifice** available from 30 – 300 µm.
- The orifice is specifically designed for plasma sampling, using pre-thinned material for the laser drilled component.
- The ion extraction optics are software controlled and optimised for minimum plasma perturbation.
- The optics are **fully tuneable** for optimum detection of +ve and –ve ions as well as electrons and radicals.

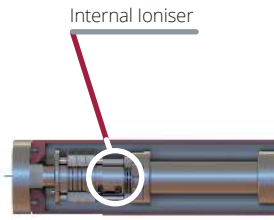


EQP PLASMA SAMPLING INTERFACE

Integral Ionisation Source

- The integral ioniser is **fully software controllable** offering precise control of electron energy **(0-150 eV)** and thermionic emission **(0.2-2000 µA).**
- **Two oxide coated iridium filaments,** with a radially symmetrical cage offering **Electron Impact, Appearance Potential and Soft Ionisation modes** for powerful characterisation of the neutral and radical species from the plasma.
- A key feature of the EQP ionisation source is the confinement of the electrons in the source cage, allowing **precise control** for appearance potential measurements for the analysis of radical species and energetic neutrals.
- Optionally, **Electron Attachment Ionisation** allows for the analysis of electronegative species from the plasma. This feature provides valuable information of radical species from electronegative plasmas.

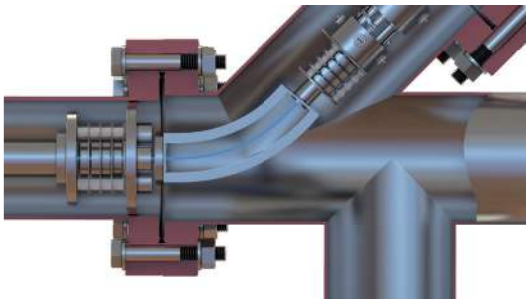




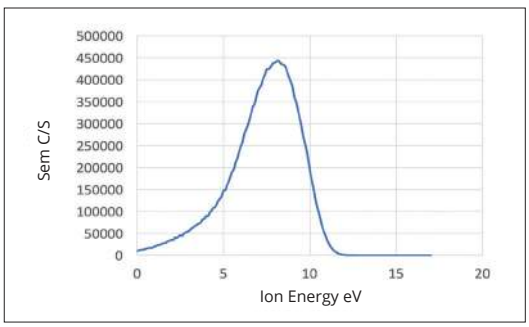
EQP IONISATION SOURCE

Energy Analyser

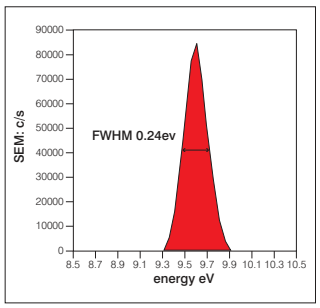
- The EQP analyser offers **constant transmission** at all energies with minimum perturbation of the ion flight path.
- The 45° electrostatic parallel plate energy analyser is used to provide minimum perturbation of the ion flight path within the analyser for **optimum energy resolution.**
- Constant transmission for ion energy distribution functions throughout the ion energy range **+/- 100 eV or +/- 1000 eV.**
- Software controlled Energy scan increments are from **0.05 eV, with a <0.25 eV FWHM** energy resolution.
- The EQP system can be **floated to 10 keV** with an external power supply and isolation components.



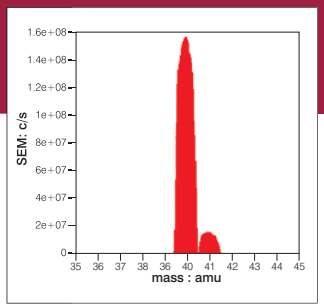
EQP 45° ENERGY SECTOR ANALYSER



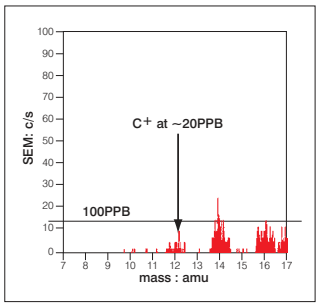
EXAMPLE DATA SHOWING TYPICAL ENERGY SPECTRUM



EQP ENERGY RESOLUTION



EQP ABUNDANCE SENSITIVITY - Typical Ar^+ and ArH^+ mass resolved spectrum



EQP SENSITIVITY - 20 ppb detection of C^+ ions from CF_4 plasma



EQP-6 3F MASS ANALYSER

Detector

- A digital ion counting detector is included as standard with **7-decade continuous dynamic range.** Counting is via a 32-bit counter for 1 c/s resolution.
- A Faraday Cup option extends the range up to **5 x 10^{10} c/s** for high density plasma applications.
- The EQP **MASsoft Professional** software provides data acquisition as raw counts, counts per second or integrated counts. Averaging or accumulating counts over repeated mass and energy scans significantly increases the signal to noise ratio in the analysis of minor components.
- A **TTL output** of raw counts is available via an external connector on the EQP electronics system.
- Signal gating with **100 ns time resolution** for energy & mass distributions.
- Optional integrated Multi-Channel Scalar (MCS) device offers **50 ns time resolution** for transient event analysis such as **HiPIMS, plasma ignition/modulation/extinction experiments** and ion flight time measurements.

Mass Analyser

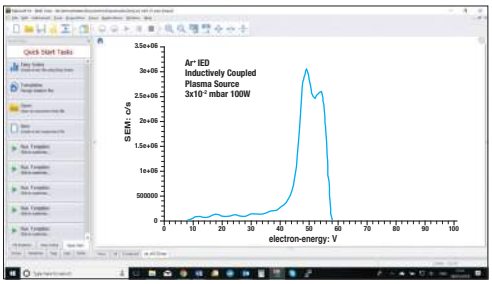
- A Hiden high performance triple filter mass spectrometer is included with the EQP system.
- Mass range options of **20, 50, 200, 300, 510, 1000, 2500 and 5000 amu** are offered.
- **6, 9 and 20 mm** quadrupole diameters are offered for specialist plasma sampling applications.
- The triple mass filter system comprises a main filter featuring RF and DC filtering, coupled with RF only pre and post filters. This technology minimises the effects from fringe fields at the primary mass filter entrance and exit, enhancing mass resolution and transmission. **Triple filter technology** allows high mass species such as clusters and metallic compounds used in plasma deposition to be analysed.
- Abundance sensitivity is to **0.1 ppm** and minimum detection of plasma species is **20 ppb.**
- Mass filter rods are precision machined from molybdenum with radially supported precision ceramics.

Hiden EQP Plasma diagnostics Systems

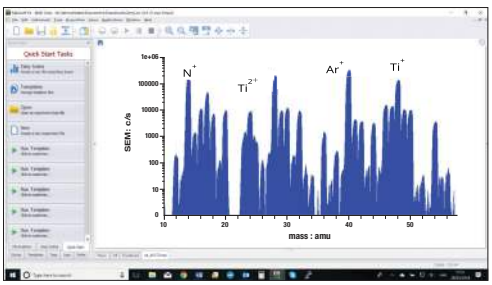
The Hiden EQP System is an advanced plasma diagnostic tool with combined high transmission ion energy analyser and quadrupole mass spectrometer, acquiring both mass spectra at specified ion energies and ion energy distributions of selected plasma ions. The advanced EQP ioniser provides for neutral and radical detection, the electron attachment ionisation feature further enhancing the detection capability for radicals in electronegative plasma chemistries.

- **High Sensitivity**
  Sub ppm detection of plasma ions, neutrals and radicals.
- **Ion Energy Analysis**
  Ion Energy distributions of plasma ions are acquired in seconds, **100 eV and 1000 eV** energy range versions are available.
- **HiPIMS, Afterglow, Pulsed and Laser Ablation**
  A standard TTL signal gating input is included for **time resolved studies.** The programmable signal gating option provides for automatic data acquisition for defined time slices through the plasma pulse. Gating resolution is **100 ns.**
- Optional innovative Multi-Channel Scalar (**MCS**) device integrated into controller firmware and MASsoft Professional software.
- 6000-bin multichannel scalar resolution offering **50 ns time resolution** with data intuitive to obtain and can be manipulated in external programmes such as Excel and Origin.
- **Positive and Negative**
  Ion Measurement Pre-set software modes enable automatic switching between **positive ion, negative ion and neutral analysis modes.**
- **Neutral and Radical Detection**
  The EQP integral electron impact ioniser provides for analysis of neutral and radical species.
- **Electron Attachment Ionisation**
  This technique of soft ionisation offered as an option for the analysis of electronegative species in plasma, further enhances the analysis of **neutrals and radicals.**
- **Appearance Potential Spectra**
  The EQP ioniser features precision control of all ion source parameters, including the facility to accurately scan electron energy for appearance potential spectra of selected species. The appearance potential spectra provide direct information to confirm the fragmentation and excitation state of plasma neutral species.

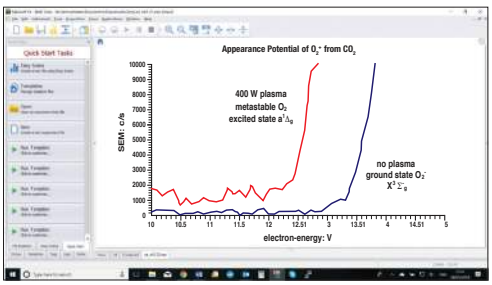
EQP OPERATING MODES



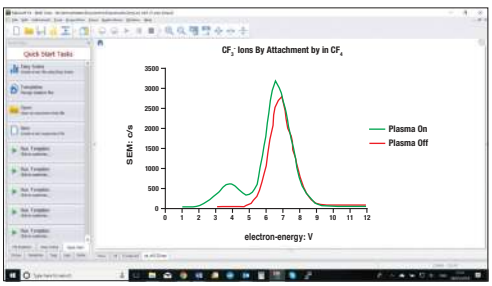
ION ENERGY DISTRIBUTIONS of selected +ve and -ve ions



MASS SPECTRA at selected ion energies for +ve ions, -ve ions and neutrals.



APPEARANCE POTENTIAL SPECTRA for identification of radical species from parent stable molecules.

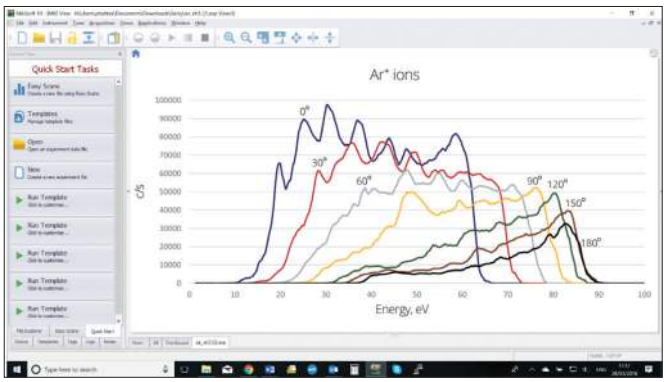


ELECTRON ATTACHMENT IONISATION scans to identify radical species produced in the plasma from electronegative gases.

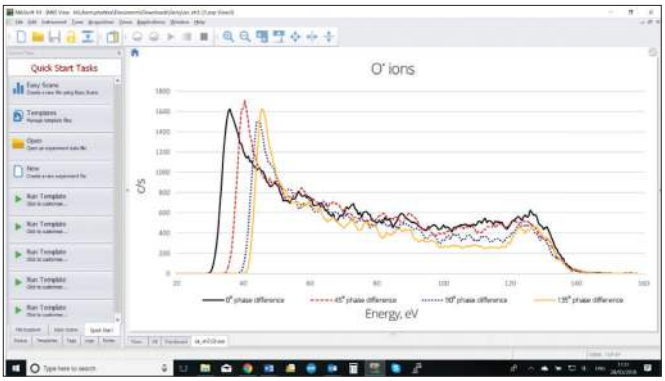
Example EQP Data

Ion Energy Distributions in dual frequency RF Plasmas

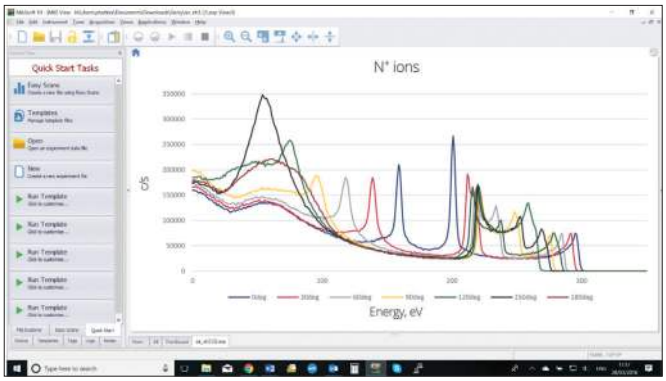
Ion energy distributions (IEDs) for both positive and negative ions have been measured, using a mass/energy spectrometer system, for two plasma reactors which can be operated using a combination of two RF power sources. One reactor uses capacitively-coupled inputs and the other includes an inductively-coupled input. Typical data for 2.26, 13.56 and 27.1 MHz inputs are presented for a range of phase relationships. The IEDs clearly show significant differences between the data for different species of ions. The differences result, in part, from the ion-molecule collisions occurring particularly in the plasma/surface sheath regions.



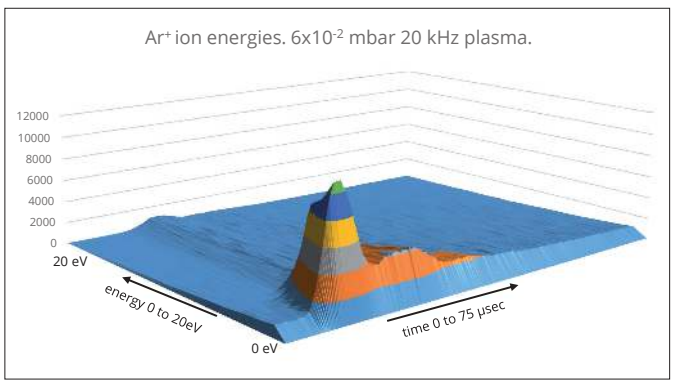
IEDs for argon plasma at 2.5x10^{-2} mbar with 13.56 and 27.12 MHz for phase differences 0° to 180°.



IEDs for O^- ions from a nitrous oxide plasma at selected phase differences.



IEDs for N^+ ions in nitrogen plasma at 6x10^{-2} mbar for mixed 2.26 and 13.56 MHz signals for selected phase differences.

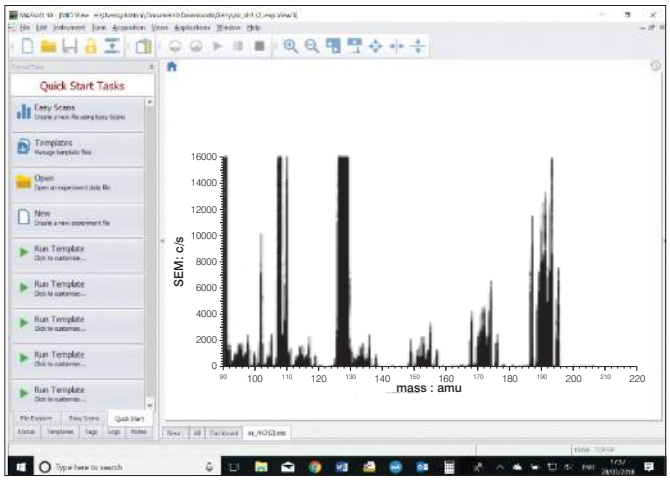


Time Resolved Ar^+ Ion Energy Distributions in RF Plasma

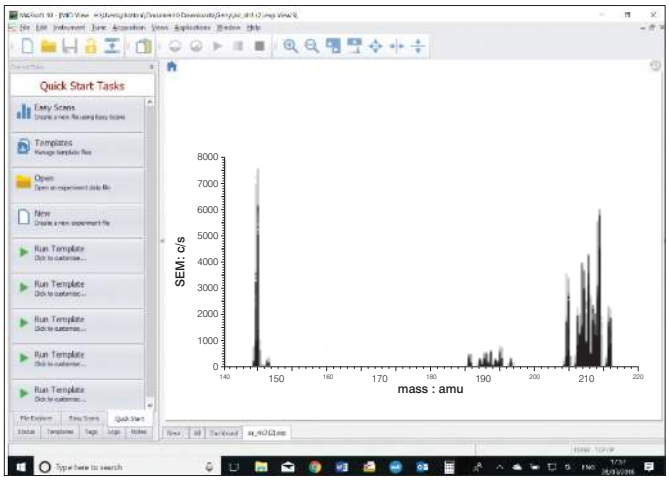
- Parallel-plate Argon plasma driven by a 20 kHz AC supply.
- MCS device used to collect mass resolved ion energy distributions for Ar^+ plasma at 200 ns intervals.
- Data shows ignition and decay of features in the ion energy spectra that are not possible to obtain with time averaged data.

Example EQP Data

MAGNETRON SPUTTERING – POSITIVE AND NEGATIVE ION MASS SPECTRA

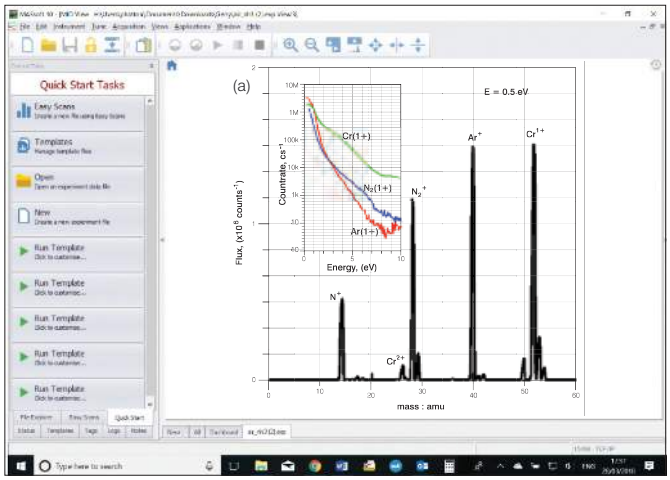


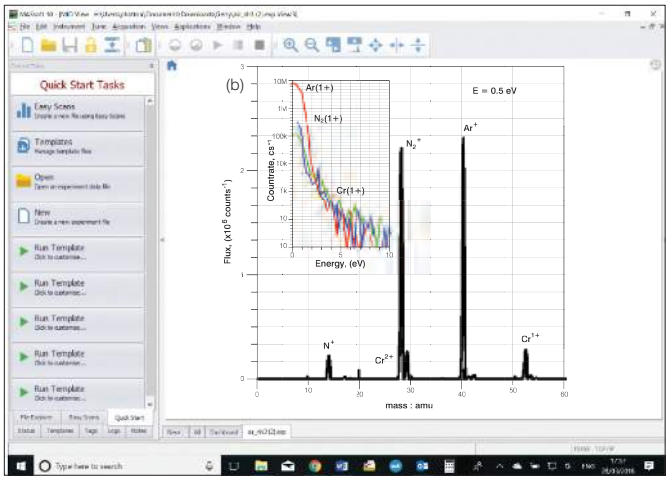
POSITIVE IONS Molybdenum Cathode. Sulphur Hexafluoride Gas. Mass spectrum 90 to 220 amu, showing Molybdenum Fluoride Ions.



NEGATIVE IONS Molybdenum Cathode. Sulphur Hexafluoride Gas. Mass spectrum 140 to 220 amu, showing SF_6^-, MoF_5^- and MoF_6^- Ions.

HIPIMS AND CONVENTIONAL SPUTTERING COMPARED – MASS AND ENERGY SPECTRA





Mass and energy spectra of (a) HIPIMS of Cr and (b) conventional dc sputtering of Cr in Ar and N_2 atmosphere as used to deposit the CrN/NbN nanolayer coating.

Data ref: Purandare, Ehiasarian and Hovsepian. *J.Vac. Sci Technol. A 26(2).*

EQP System Configurations



System Options

The EQP system can be configured with a wide range of customised options to suit many plasma conditions. These include:

Option	Part No.
1000 eV energy range	620100
Dual Faraday/ Electron Multiplier Detector	443020
Extended Flight Tube 321 or 400 mm	620200
Extended Flight Tube to 750 mm	620400
Magnetic Shielding to 800 Gauss	610201
Magnetic Shielding to 500 Gauss	610211
Electron Attachment Ionisation	610320
DC Driven Electrode 44 mm diameter	618010
RF/DC Driven Electrode 150 mm diameter	618020
Water Cooled RF/DC Electrode 84 mm diameter	618030
4.5" UHV Gate Valve	202350
Z-drive 4" Stroke – Manual	202500
Z-drive 12" Stroke – Motorised	202900
Front End Shutter	610440
RIV60 Re-Entrant Isolation Valve	610450
PC Computer with MASsoft Professional Software Pre-Installed	800624
Windows NIST MS Database	800500
0-10 volt 8 Channel Analogue Output Card	304908
Penning Gauge and Controller incl. Vacuum Interlock for System Protection	303805
Programmable Signal Gating with Foreground and Background Delay Timers	110600
Multi-Channel Scalar (MCS) Mode for 50 ns Time Resolution	800404
HPR-60 Molecular Beam Sampling Option for Atmospheric Plasma Sampling	303065

EQP Mass Spectrometer Range

- **EQP-6**
  6 mm quadrupole rod diameter
  - Mass range options 300 and 510 amu
- **EQP-9**
  9 mm quadrupole rod diameter
  - Mass range options 50, 300, 510, 1000, 2500 and 5000 amu
- **EQP-20**
  20 mm quadrupole rod diameter
  - Zone H Mass range 20 amu
  - Zone 1 Mass range 200 amu

Plasma Pressure Options

- Up to 0.5 mbar – Differential pumping with a 60 l/s turbomolecular pump
- Up to 2 mbar – Differential pumping with a 240 l/s turbomolecular pump
- > 2 mbar - EQP system is upgradeable to the multi stage HPR-60 molecular beam sampling system

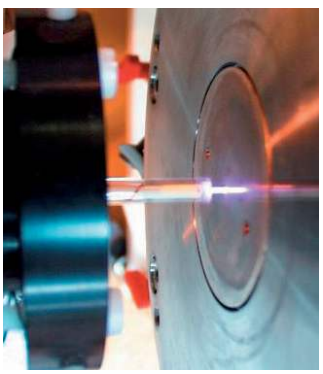
Plasma Applications

EQP systems are offered with a range of standard plasma sampling options to provide non-invasive sampling of a broad range of plasma applications including:

- HiPIMS
- ECR – Electron Cyclotron Discharge
- Magnetron Discharge
- Helicon Source
- DC Glow Discharge Plasma
- Pulsed Plasma & Laser Ablation
- Parallel Plate – RF Plasma
- ICP – Inductively Coupled Plasma



EQP SYSTEM in plasma



PLASMA NEEDLE - atmospheric plasma - analysis with EQP/HPR-60 molecular beam sampling system.

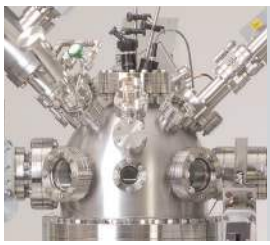
HidenAPPLICATIONS

Hiden's quadrupole mass spectrometer systems address a broad application range in:

GAS ANALYSIS

- dynamic measurement of reaction gas streams
- catalysis and thermal analysis
- molecular beam studies
- dissolved species probes
- fermentation, environmental and ecological studies



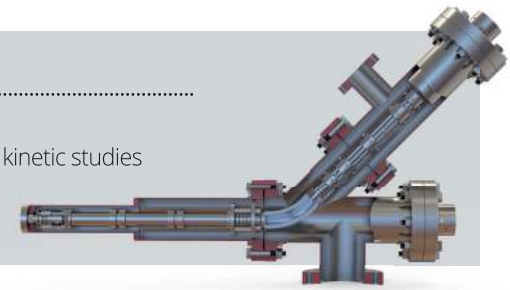


SURFACE ANALYSIS

- UHV TPD
- SIMS
- end point detection in ion beam etch
- elemental imaging – 3D mapping

PLASMA DIAGNOSTICS

- plasma source characterisation
- etch and deposition process reaction kinetic studies
- analysis of neutral and radical species





VACUUM ANALYSIS

- partial pressure measurement and control of process gases
- reactive sputter process control
- vacuum diagnostics
- vacuum coating process monitoring

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