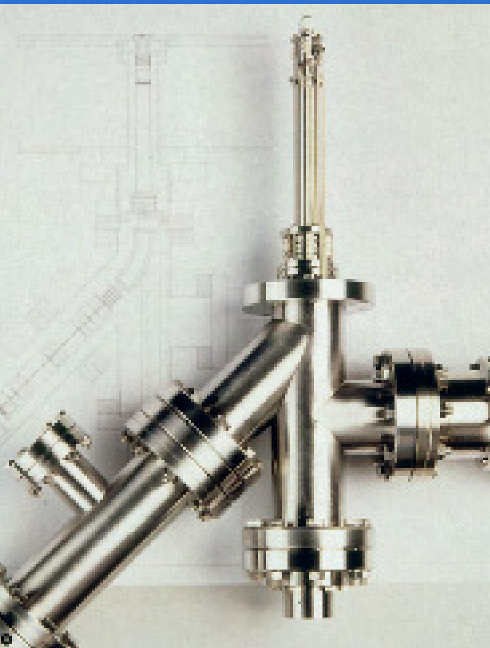
Hiden EQP Systems

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



vacuum analysis

surface science

gas analysis

plasma diagnostics

HIDEN ANALYTICAL

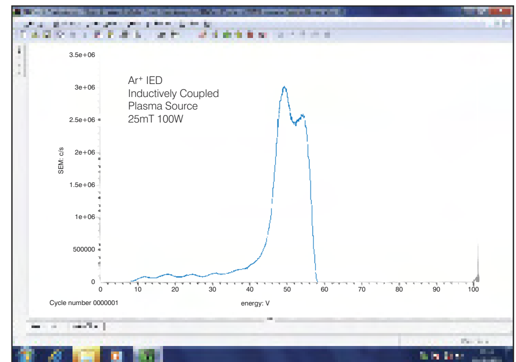
Hiden EQP Plasma Diagnostic Systems

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.

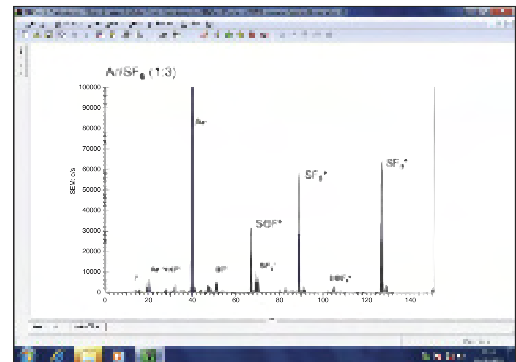
- **High Sensitivity**
  Sub PPM detection of plasma ions, neutrals and radicals.
- **Ion Energy Analysis**
  Ion Energy distributions of plasma ions are acquired in seconds, 100 eV and 1000 eV energy range versions are available.
- **Afterglow, Pulsed Plasma, and Laser Ablation**
  A standard TTL signal 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 nanoseconds.
- **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

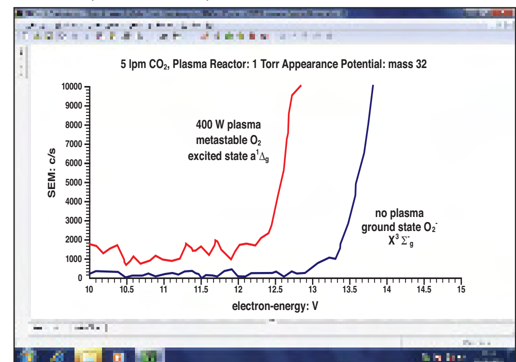
- ***Ion Energy Distributions** of selected +ve and -ve ions.*



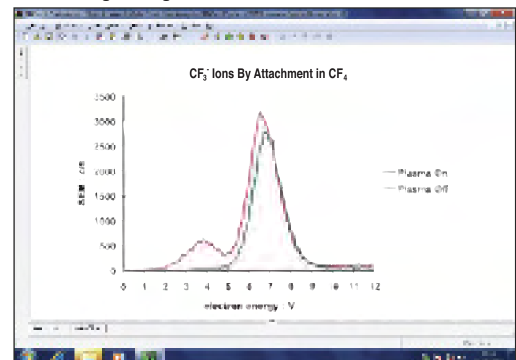
- ***Mass Spectra** at selected ion energies for +ve ions, -ve ions and neutrals.*



- ***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.*



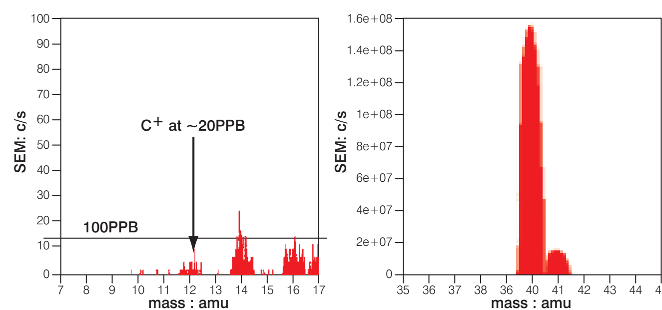
The HIDEN EQP - The Mass/Energy Analyser for Plasma Diagnostics & Characterisation

Plasma Sampling Interface

- A range of laser drilled orifices from 30μm diameter. The orifice design is optimised for plasma sampling using pre-thinned material for the laser drilled component.
- Software controlled ion extraction optics provide for plasma sampling with minimum perturbation of the plasma.
- A standard connection is included in the EQP electronics to allow the EQP system to be referenced to an external supply, a plasma electrode for example. This feature enables ion energy distributions to be referenced to the substrate's self bias.
- Plasma electrodes coupled to the EQP provide a substrate platform for sampling the plasma as it interacts with the substrate during processing. Electrodes are custom designed to suit RF, DC or pulsed plasma supplies with heated substrate stages and water cooling options available.
- The EQP sampling configuration can be readily user disassembled for ioniser filament replacement and cleaning.

Internal Ioniser

- The internal EQP ioniser includes two oxide coated iridium filaments, with a radially symmetric cage. The assembly is closely coupled to the plasma sampling orifice for high sensitivity analysis of plasma gas neutrals and radicals.
- EQP software provides for precision control of the ion source operating parameters including filament emission, source cage voltage and the ionising electron energy.
- A key feature of the EQP ioniser design is the confinement of electrons within the ion cage vicinity. This allows a high degree of control for the detailed appearance potential measurements used in the analysis of radicals.
- An electron attachment ionisation option is available which allows for analysis of negative ions produced in the EQP ioniser where electronegative species are present. This technique provides valuable information in the analysis of radical species from electronegative plasmas.



EQP Sensitivity

Ion counting detector

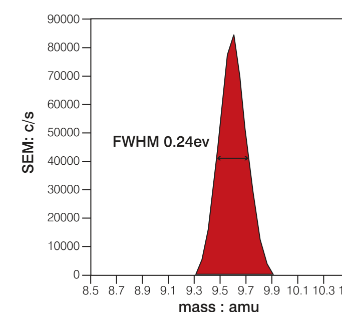
Triple filter quadrupole mass analyser

45˚ Sector field energy analyser

Internal Ioniser

Ion flight tube to provide plasma sampling insertion from 240mm up to 750mm

Turbo molecular pump port



EQP Energy Resolution

Energy Analyser

- The EQP high transmission energy analyser provides ion energy distributions of selected ions within the plasma. For example, the energy with which each species is interacting with the substrate - critical information in low damage etch.
- A 45 degree sector field energy analyser is used to provide minimum perturbation to the ion flight path within the analyser for optimum energy resolution.
- The EQP energy analyser provides constant transmission and constant energy resolution functions throughout the ion energy range (+/- 100 eV, +/-1000 eV)
- The energy resolution of the sector field energy analyser is better than 0.25 eV FWHM.
- Energy scanning for all ions is automatically controlled with energy increments selectable from 0.05 eV.
- The EQP system is floatable to 10 KeV using external power supplies and isolation components.

Mass Analyser

- A triple filter mass analyser construction is included in the EQP system. The triple mass filter has short 'RF only' pre and post filters which minimise effects from fringe fields at the primary mass filter ion entrance and exit. This enhances peak separation and transmission particularly for high mass species. This triple filter configuration has been proven superior in performance to single filter quadrupoles in recent years.
- Abundance sensitivity is to 0.1PPM. Detection to 20PPB is available for non-interfering species.
- The mass filter rods are precision ground from molybdenum with precision machined radially supporting ceramics for high performance, durability and long term stability.

Detector

- An ion counting detector is included as standard offering seven decades continuous dynamic range.
- Counting is via a 32 bit counter for 1c/sec resolution throughout the range.
- A Faraday cup option extends the range up to 5 x 10^{10} c/s for high density plasma applications.
- The EQP software provides for data acquisition as raw counts, counts per second, averaged counts per second or integrated counts. Averaging or accumulating counts over repeated mass and energy scans significantly increases signal to noise in the analysis of minor components.
- A TTL output of raw counts is available via a connector on the EQP electronics system.
- A signal gating input is included as standard to provide for time resolved plasma studies with a resolution of 100 nanoseconds suited to pulsed plasma or laser ablation applications. The programmable signal gating option provides for automatic data acquisition for a defined time slice through the plasma pulse.

EQP Systems Configurations:

EQP 300 – 300 AMU mass range
EQP 500 – 510 AMU mass range

EQP systems include a 6mm pole diameter triple filter quadrupole mass spectrometer.

EQP 1000 series

Available configured for mass range 50, 300, 510, 1000, 2500 AMU

EQP1000 series systems include a 9mm pole diameter triple filter quadrupole mass spectrometer for enhanced abundance sensitivity and high mass range capability.

A 200Watt remote RF/DC power supply is included with EQP 1000 series systems.

EQP Systems are offered with a range of standard plasma sampling options to provide a non invasive sampling interface for a broad range of plasma applications including:

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

Plasma pressure:

up to 0.5mbar - EQP systems require differential pumping with a 60l/sec turbomolecular pump.

up to 2mbar - EQP systems require differential pumping with a 240l/sec turbomolecular pump.

> 2mbar - The EQP system is offered with the HPR 60 molecular beam sampling series with multi stage differential pumping.

System options include:

1000 eV energy range
– 100 eV energy range is standard.

Magnetic shielding
– standard options include 500 Gauss front end shielding or 800 Gauss complete system shielding.

Water cooling
– for high density plasma applications – water cooling is required where the temperature is expected to exceed 300˚ C.

Driven electrode
– sampling with RF or DC biased electrode - recommended for applications where direct information about plasma interaction with the substrate under substrate bias conditions is a necessity.

Z-drive bellows sealed translator
– with gate valve to provide for sampling across the plasma volume, and for vacuum isolation of the EQP system.

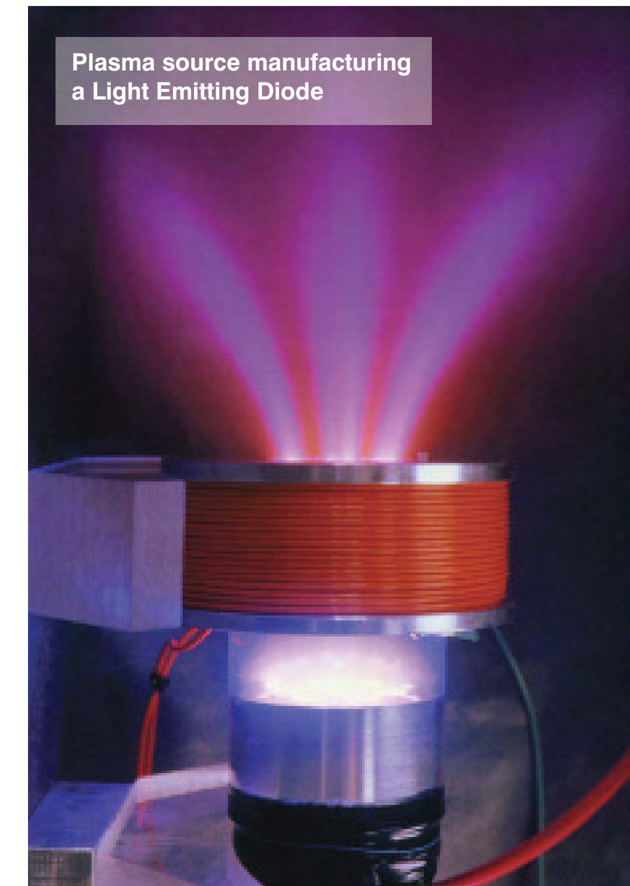
Insertion length options up to 750mm

Programmable signal gating
– recommended for pulsed plasma applications and for systems including molecular beam sampling with chopper.

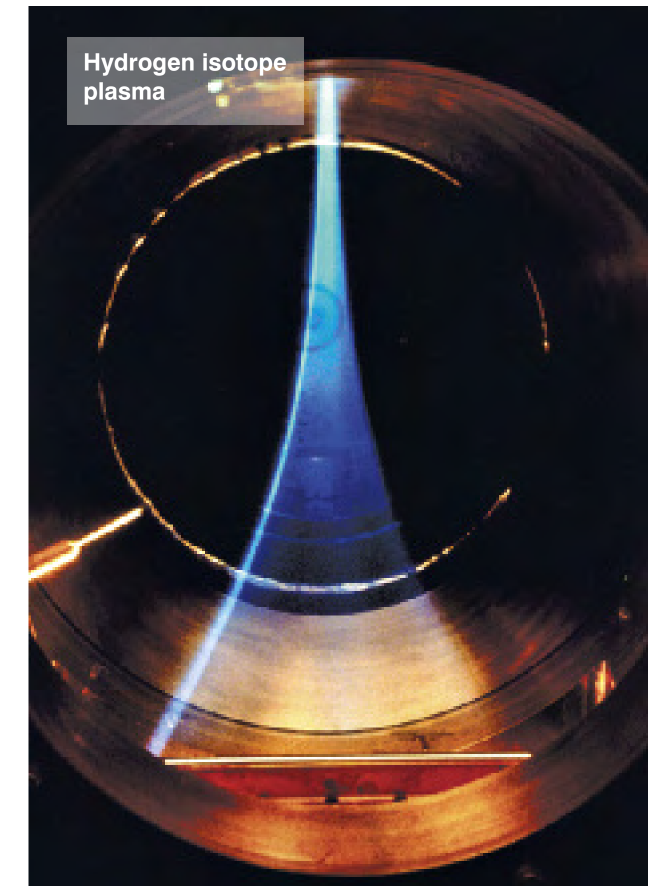
HPR-60 MBMS
– molecular beam sampling for high pressure plasma.

EQP Systems for Plasma Applications

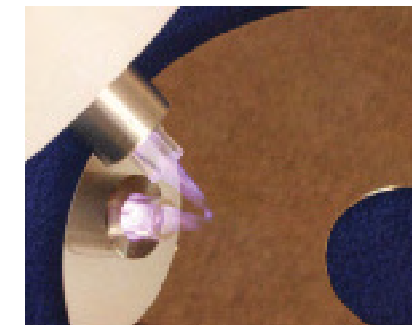
• Etching • Deposition • Coating • Process Development

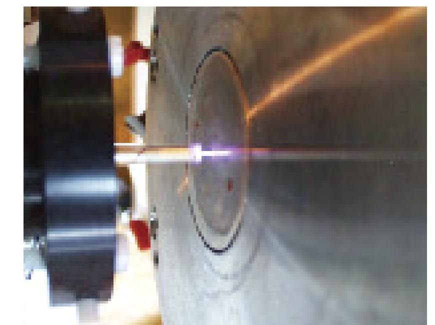


Plasma source manufacturing a Light Emitting Diode

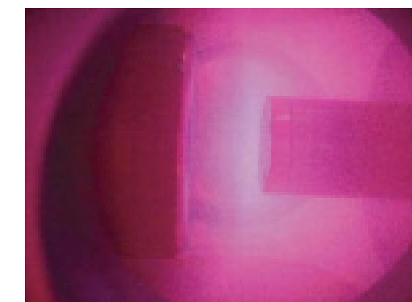


Hydrogen isotope plasma

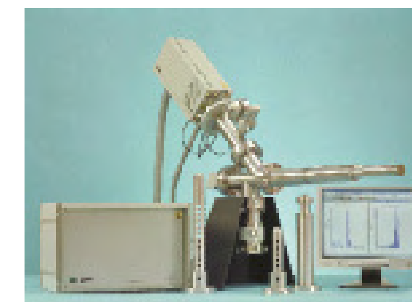




Plasma needle - atmospheric plasma - analysis with EQP/HPR 60 molecular beam sampling system.



EQP system - in plasma

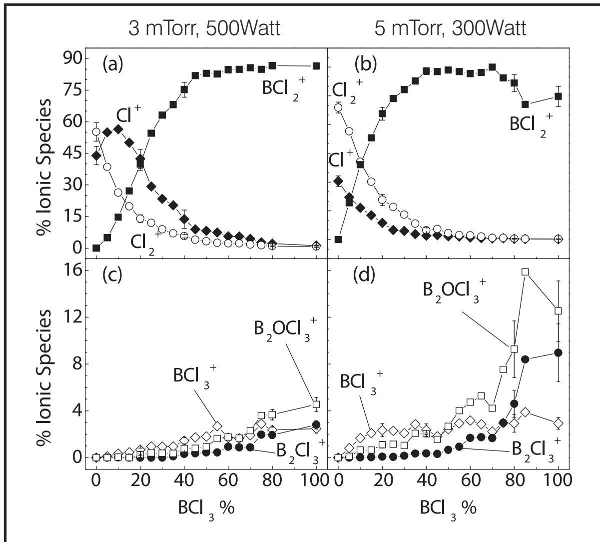


- with cover tube options for SIMS

- with driven electrode.

EXAMPLE EQP DATA

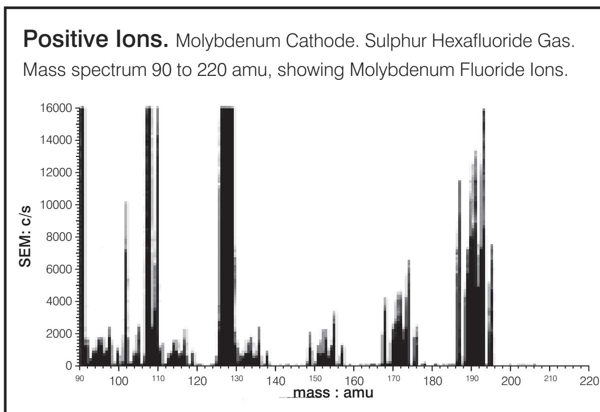
Plasma etching of Hf-based high k thin films



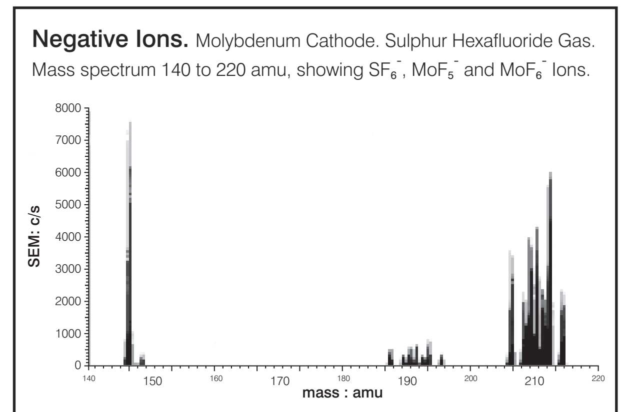
QMS-measured plasma ionic species are shown in (a) and (b). Higher mass ionic species measured by QMS are shown in (c) and (d). The data in the left column are taken at 3 mTorr and 500W (high density plasma condition) while those in the right column are taken at 5 mTorr and 300W (low density plasma condition).

Data ref:
Ryan M. Martin, Jane P. Chang
University of California, Los Angeles, USA.
J.Vac. Sci. Technol. A 27(2)

Magnetron sputtering – Positive and negative ion mass spectra

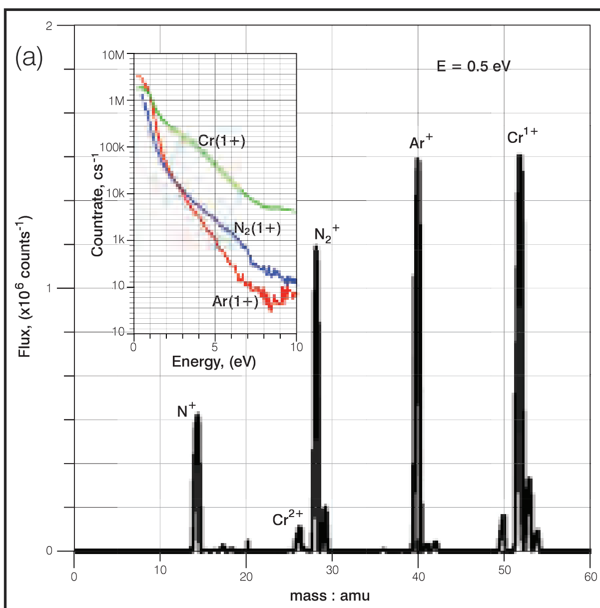


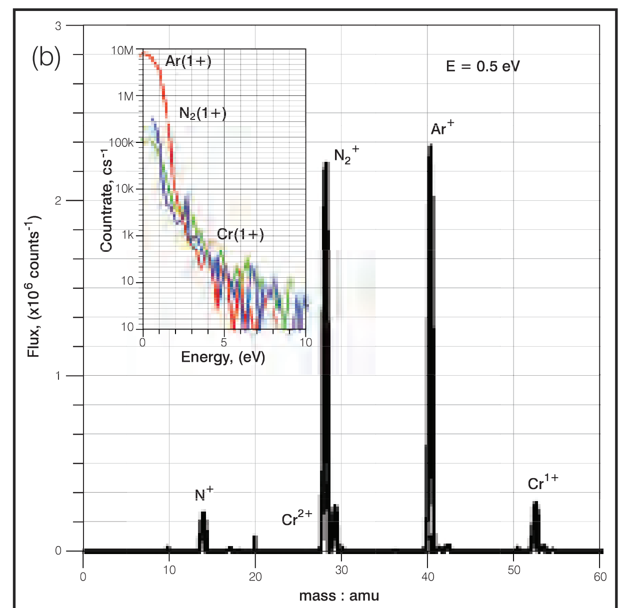
Positive Ions. Molybdenum Cathode. Sulphur Hexafluoride Gas. Mass spectrum 90 to 220 amu, showing Molybdenum Fluoride Ions.



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).*

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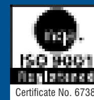

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It is Hiden Analytical's policy to continually improve product performance and therefore specifications are subject to change.

TECHNICAL DATA SHEET 172