• Introduction to the market in Feb 2017
• Had to trailblaze as there were no serious similar products
• Over 200 global sales to date (US, Europe, China, Japan, Korea)
• Customers including Apple, CERN, GKN, Guardian Glass, PPG, Lawrence Livermore National Laboratory
RPEM principal

Spectrum analysis gives species composition and concentration
Optix plasma generation

- Inverted magnetron plasma generator
- Similar to a cold cathode pressure gauge
- Plasma is current regulated to maintain stability at higher pressures
Optix pressure range

Pressure range

Plasma light intensity too low

1E-10 1E-8 1E-6 1E-4 1E-2 1

Operating Pressure (mBar)

1E-6 mbar – 0.5 mbar

OPTIX

RGA

RGA with differential pump

Plasma has some non-linearity
Typical vacuum deposition and surface treatment pressure ranges

- **Evaporation**
- **Sputtering**
- **CVD / PECVD**
- **Plasma surface treatment**

Optix pressure range

- **0.5 mbar**

Quadrupole RGA

1E-6 1E-5 1E-4 1E-3 1E-2 1E-1

Pressure (mbar)

Differentially pump

Atmosphere
Robustness

• No filament

• Interlocked via internal pressure gauge

• Easily cleanable and replaceable electrodes
Common questions from RGA users

How sensitive is it?

• The sensitivity of Optix is reduced as pressure increases above 1E-4mbar
• Gas dependent – smaller molecules are generally less sensitive
Common questions from RGA users

Mass vs Optical spectrum

Mass Spectrum

Optical Spectrum – Intensity corrected

Wavelength (nm)
Common questions from RGA users

**Equivalent AMU range**

- The plasma inside the Optix will break larger molecules into smaller components
- Prominent, defined peaks from component species

Isopropanol (CH$_3$CHOHCH$_3$)

- Can directly observe up to tri-atomic molecules
  - c. 50 AMU
- Can indirectly observe very large molecules via fragmentation
  - c. 100s AMU
### Optix vs RGA summary

<table>
<thead>
<tr>
<th>OPTIX – remote plasma gas analysis (RPGA) Optical method</th>
<th>Quadrupole Residual Gas Analyzers (RGAs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robust– detector separated from chemicals by optical window</td>
<td>Detector in contact with chemicals – easy to contaminate, hard to clean</td>
</tr>
<tr>
<td>No filaments – simple electrode geometry</td>
<td>Filaments and ionizers are consumables</td>
</tr>
<tr>
<td>Operates 0.5 to 10⁻⁶ mbar</td>
<td>Only operates reliably down to 10⁻⁴ mbar</td>
</tr>
<tr>
<td>Direct chamber monitoring – no need for differential pumping unless atmospheric sampling</td>
<td>Higher than 10⁻⁴ mbar pressure needs differential pumping – loss of sensitivity</td>
</tr>
<tr>
<td>FAST – ‘speed of light’, 10-50 msec response</td>
<td>Typically 0.5 to several seconds range</td>
</tr>
<tr>
<td>Tolerates volatiles in the vacuum – hydrocarbons, solvents, long chain polymers</td>
<td>Only small amounts of contamination before sensor failure</td>
</tr>
<tr>
<td>Wide range of useful software applications available – gas tracking, leak detection, pump-down monitoring, water tracker, end-point detection, multi-mode process tracking</td>
<td>Typically gas tracking &amp; leak detection</td>
</tr>
<tr>
<td>Sensor degassing mode – avoid false reading</td>
<td>Yes, but degas can affect filament lifetime</td>
</tr>
</tbody>
</table>
Application examples – Water and Air

- Example of “Clean” vacuum system
- Mainly water vapour – OH and H emissions
- Small amount of N$_2$ in relation to water vapour
- General rule that < 1E-2 mbar a leak tight system should not have significant N$_2$ present

OH > N$_2$ – Leak tight
Application examples – Water and Air

N2 > OH ..... Leak very likely!
Application examples – Gas line check

- Ar process gas line contaminated with air
- MFC feedback would have shown no problem, Pressure gauges would also not detect the problem
- **No system leak to detect** – in situ gas monitoring only way to see this

Residual Ar bled out of line and replaced with air leak
Application examples – Water

Direct sensing

- Optix can directly sense the vacuum: *Pressure 0.1 mbar*
- **Enhanced sensitivity for condensable species**

**Water vapour - 309.6 nm (OH), 18 AMU**

Magnetron turned off and on – OPTIX detects moisture increase as gettering is stopped

Moisture condenses on the surfaces of the RGA differential pumping set and does not reach the detector
Application examples – Water

Direct sensing

Hydrogen - 656 nm, 2 AMU
Application examples – Water

Direct sensing

The effect of atmospheric exposure on water vapor concentration

Pumping time based on residual water vapor

- 5 minutes exposure
- 1 hour exposure
- 24 hour exposure
- 48 hour exposure
Ar / O2 dry etch monitoring

- **Process pressure: 5E-2 mbar**
- **Oxygen consummation and CO2 production during photoresist etching**
- **Comparison between wafer with photoresist applied and without**

![Graph showing etching occurring during plasma on.](image)

Image courtesy of SNT
Application examples – He leak detection

- Differential spectrum produced when spraying He around an air leak
Application examples – He leak detection

• Possible to localise air leaks by monitoring He emission

• Not a complete replacement for a dedicated He leak detector

• Leak rates are not directly quantifiable

Why not use Argon?

504nm He emission

c. 1E-6 mbar/l/s

Ar sprayed near door leak
Application examples – Target cleaning

- Very large H outgassing – taking significant time to reach steady state
- Other species also observed initially outgassing – OH, CO2, O
- Subsequent power increases cause increased H outgassing and additional settling time
- Consumption of N2 also observed – small chamber leak
Partial pressure feature

- Raw gas readings are interactive (relative to each other)
- Results are more like ratios of gases

**QMS RGA**

**Optix (Raw data)**
• Optix has a patented algorithm that transforms the readings into **partial pressures**

![Graph showing partial pressures](image-url)
Included software

Ease of use

- Optix software is simple and easy to use
- Powerful analysis options (spectrum auto ID)
- Flexible options for integrating with PLCs
Alternative configurations

Versatility

Standard OPTIX package, plasma generator with power supply (DC as standard, pulsed DC as an option) with Spectrometer head and OPTIX software package / cables

Standard OPTIX package, with optional optical fiber link between sensor and spectrometer – increases flexibility of the package – use items separately

Plasma generator with power supply (DC as standard, pulsed DC as an option) and cables – generates an intense plasma over a wide pressure range – can link to Speedflo or other control platforms

Spectrometer head with OPTIX software package – take advantage of the OPTIX software suite to manage your plasma monitoring and take advantage of the communication and trigger facilities
Optix can also be configured to analyse and monitor the process plasma (i.e. deposition source plasma)

Alternative configurations

Mode (1): “RGA mode”. The Optix functions like a QMS RGA, monitoring the gaseous species in the vacuum environment. No process plasma is required. Can be used to monitor the pump down, analyse outgassing, leak detection etc...

Mode (2): Monitoring the process plasma. Can be used to analyse ionisation, gas composition of the plasma, substrate interaction etc. If no direct line of sight is available to the process plasma then in-vacuum fibre optics can be used.
Highly robust and easy to use – no filaments to replace & easy to use software

OPTIX can work at all process pressures – no need to differentially pump unless atmospheric sensing

Highly mobile – can be carried in a small bag for on-site trouble shooting

OPTIX is less sensitive to contamination than RGA’s, can be used for ’dirty’ hydrocarbon environments as well as etch, CVD and ALD type processes

This sensing technique offers a lower cost and lower complexity solution than alternative methods

Can link directly to Speedflo reactive gas controller or PLC for feedback control