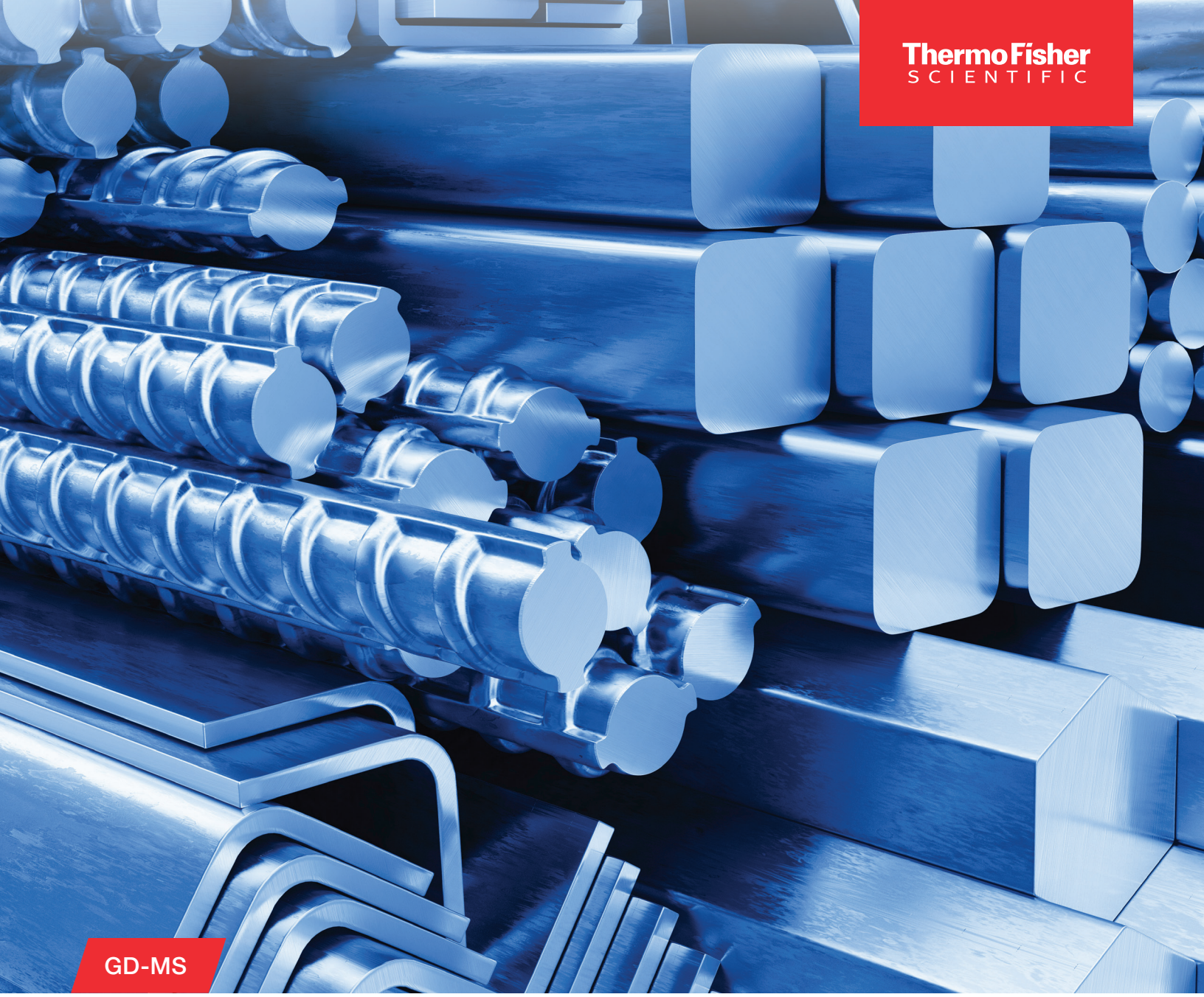


Redefine quality

Element GD Plus Glow Discharge Mass Spectrometer

thermo scientific

Redefine quality for elemental analysis of solid samples

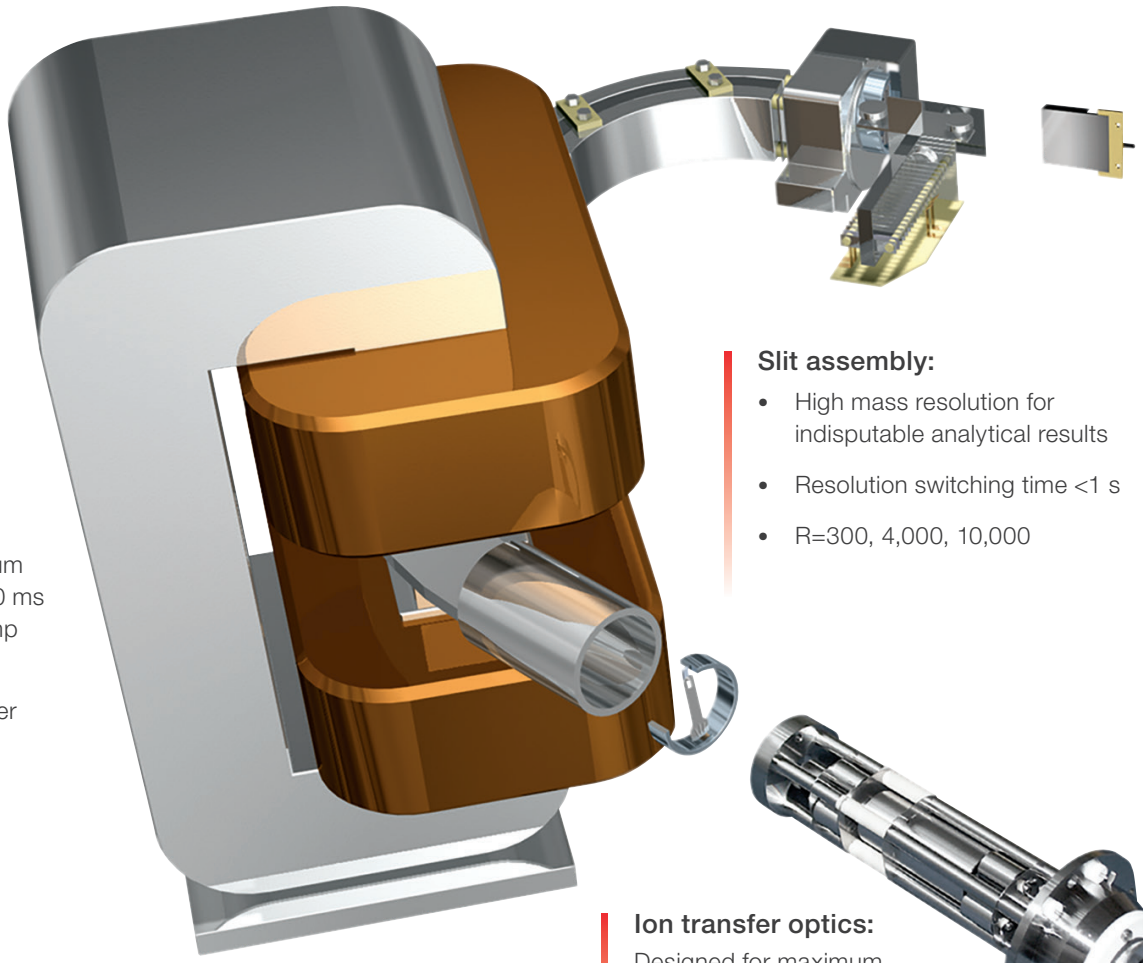
The Thermo Scientific™ Element GD Plus™ GD-MS redefines the analysis of advanced high purity materials in solid state. For high through-put and extra low ppb level detection limits, the Element GD Plus GD-MS is the most convenient and powerful tool for bulk sample analysis and depth profiling in routine and research applications.

The Element GD Plus GD-MS enables analysis of nearly all elements in the periodic table for most conductive samples with the same level of sensitivity and data quality. Many non-conductive materials can also be analyzed by using secondary electrode techniques. Routine analysis of the low melting point metals can be achieved either using standard conditions (for metals such as indium), or with dedicated work-flow for the sample preparation and analysis (for gallium). This makes GD-MS the reliable standard for any metal analysis.

The Element GD Plus GD-MS is designed to serve the needs of high purity material manufacturers and their customers in industries such as:

- Aerospace—nickel super alloys, depth profiling of coatings and diffusion layers
- Semiconductor—silicon carbide wafers and powders
- Microelectronics—copper, alumina powder, sputter targets
- Renewable energy—silicon blocks, wafers, solar cells
- Nuclear decommissioning—graphite purity, depth profiling for screening solid samples

Electrostatic analyzer:
ion energy focusing



Slit assembly:

- High mass resolution for indisputable analytical results
- Resolution switching time <1 s
- R=300, 4,000, 10,000

Magnet:

- Designed for maximum speed. Less than 150 ms are required for a jump from ^{7}Li - ^{238}U - ^{7}Li
- Magnet coils are water cooled for maximum mass stability

Ion transfer optics:
Designed for maximum ion transmission efficiency, stability, low mass bias, and low background

Pulsed mode

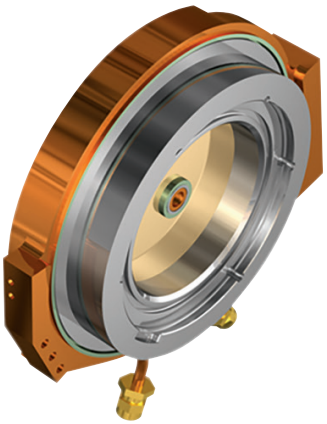
- Low energy, low heat generation
- High precision
- Suitable for depth profiling

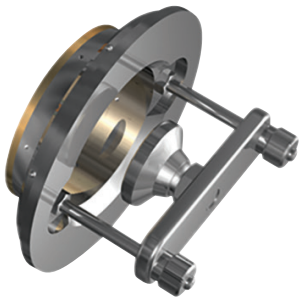
Triple detector system:

- Dual mode secondary electron multiplier (counting and analogue) plus Faraday detector
- 13 orders of linear dynamic range from <0.2 cps to >10^{12} cps enables quantification from sub-ppq to permil concentrations
- Excellent abundance sensitivity (<15 ppb) allows ppb quantification next to matrix signals

Grimm-type ion source

- Low level of polyatomic interferences
- High sputter rates = short analysis times
- Widely adjustable working range for pulsed mode operations
- Uniform crater shape, flexible anode diameter





Sample holder

- Fast and simple sample to sample switching
- Flexible cell for flat samples, pressed powders and pin samples
- Plug-in cone and anode parts for quick exchange eliminating the risk of cross contamination
- Optional Peltier cooling for gallium analysis

High productivity and low costs of analysis

The Element GD Plus GD-MS is designed to deliver outstanding sensitivity and accuracy at a high sample throughput, dramatically lowering the cost of your analysis.

Fast flow ion source

- Precise and efficient pulse mode for analysis
- High power mode for presputtering the sample surface (eliminating the need for chemical surface cleaning)
- Short pumping times: <10 min sample turnaround
- User friendly source design: <1 min sample exchange
- Short analysis time due to high sputter rates
- Electronic (Peltier) sample cooling eliminates the need for cooling with cryogenic gases

All your elements in one scan

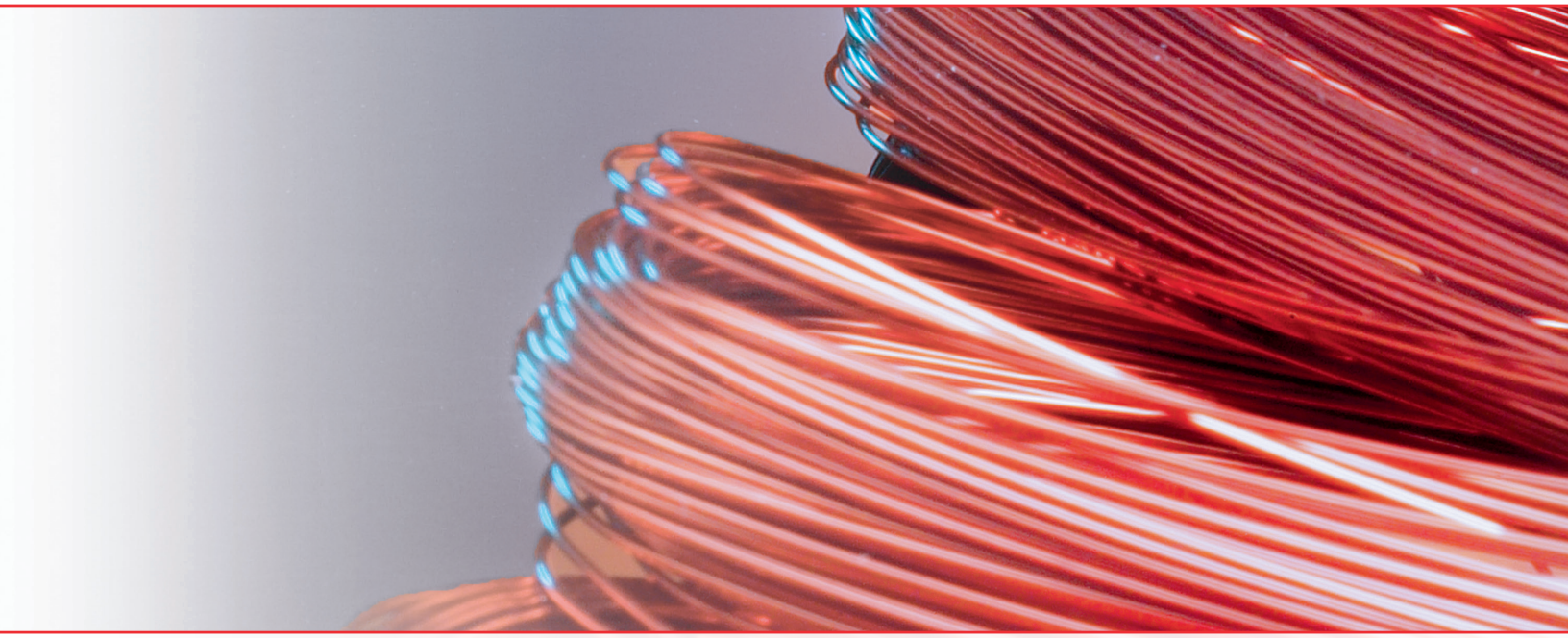
- Automatic detection system offering >12 orders of magnitude: enables matrix to ultra-trace detection capabilities in a single scan
- Quantitative multi-element analysis across the periodic table
- Resolution switching time: <1 second

Low cost of analysis

- High throughput: up to 5 samples/hr
- Fast flow vacuum is more robust against moisture within samples
- Less sample preparation: no requirement for acid cleaning of high purity samples
- Faster sample analysis: no requirement to measure calibration standards
- Simpler sample preparation compared to wet chemical analysis: no need for sample dissolution, no need for a wet laboratory

Rapid sample preparation

- Sealed sample chamber: reduces requirement for perfectly flat samples because the sample is not used as a vacuum seal
- Flexible cell for flat samples, pressed powders and pin samples (optional sample holder)



Case study

Elemental analysis of nickel alloys

Nickel alloys are heat resistant and durable under mechanical stress. This makes nickel alloy an important material for manufacturing safety-sensitive parts in the aerospace industry. Various qualities of nickel alloy are used for turbine blades of aircrafts and rockets. The trace elemental composition of these alloys must be routinely analyzed to guarantee quality.

- 14 elements analysed at ppm level using standard RSF approach
- 1 sample analyzed every 4 min:
  - 2 min sample exchange
  - 1 min pumping down
  - 45 s pre-sputter
  - 90 s analysis

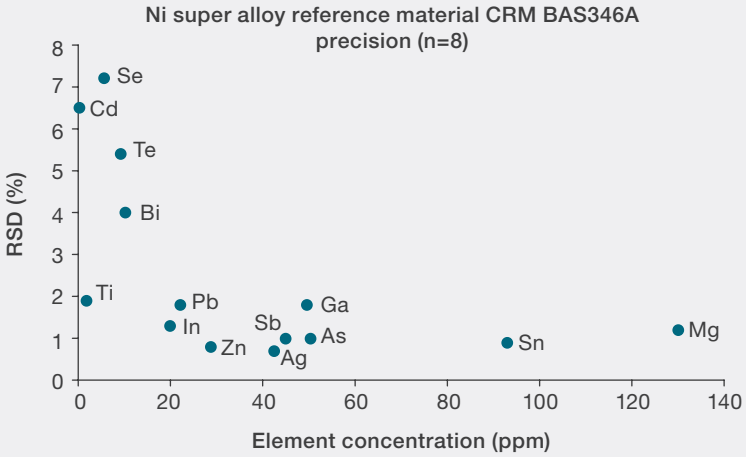


Figure 1. Typical RSDs of trace and minor elements analyzed in a high purity nickel alloy

Routine operation

The Element GD Plus GD-MS is designed with routine operation and high throughput at its core.

Easy sample handling

- Sample vacuum chamber: eliminates risk of leakage between the sample and the GD cell
- The sample can quickly and easily be removed from the ion source, simply unloaded and re-loaded, and repositioned for the next measurement
- Opening and closing of the ion source manifold is fully automatic

Easy to use software

- Robust software suite designed around productivity and ease-of-use
- Fully automated analysis and data evaluation
- LIMS connectivity with automatic data transfer
- Merge function: to combine calibrated elements and semi-quantitative (standard RSF approach) elements

Automatic detector switching

- Linear dynamic range spanning more than 12 orders of magnitude allows the simultaneous analysis of matrix elements (%), traces (ppm) and ultra-traces (ppb)
- Automatic cross calibration between different detection modes ensures robust results

Rapid determination of the trace elemental concentration

- Determine elemental concentrations rapidly within a single scan without calibration standards (using standard RSF approach)
- Excellent reproducibility of standard RSF approach:

Best precision within short analysis time: typically achieve short-term stability (10 min IBR-RSD):

<1% for minor elements at 1,000 ppm
<2% for trace elements at 100 ppm
<3% for trace elements at 1 ppm

Accuracy: Matches calibrated value within 30% for all elements

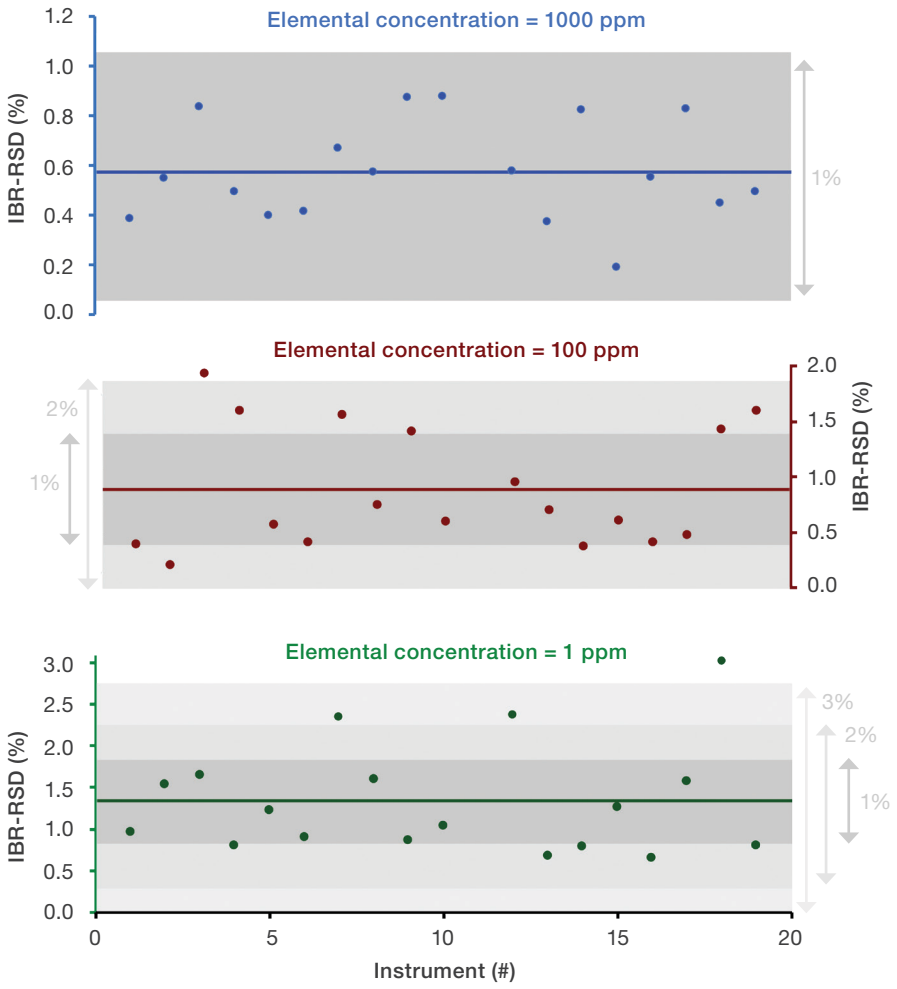


Figure 2. Ion Beam Ratio RSD for 10 min measurements of elements at 1000 ppm, 100 ppm and 1 ppm. Data shown for 18 different instruments.

Outstanding limits of detection

The Element GD Plus GD-MS delivers high through-put without compromise. With the highest signal-to-noise ratio and lowest limits of detection, this system is the workhorse for ultra-high purity elemental analysis.

Outstanding signal-to-noise ratio

- Unique ion source designed for high ion transmission, maximizing the signal analyzed
- Guaranteed signal-to-noise ratio (>2 x 10^{10} in Cu at a resolution of 4,000) produces sub-ppb limits of detection

Detection limits

- Robust sub-ppb detection limits for any sample type and for complex matrices
- Unlike solution-based techniques, there is no dependency of detection limits on sample dilution, matrix type etc
- Sub-ppb detection limits ideal for analysis of high purity metals and alloys, and for semiconductor applications

Analyze sub-ppm levels of atmospheric gas elements in samples

- Optional CNO option: cleans the incoming discharge gas, allowing low levels of detection of carbon, nitrogen and oxygen
- Achieve sub-ppm level limits of detection for carbon, nitrogen and oxygen
- No compromise to the through-put of your analysis: all elements can be measured on one instrument in a single scan

Elimination of unwanted interferences

- Outstanding abundance sensitivity (typical to achieve 6 ppb for 62 amu/^{63}Cu)
- Factor 10 reduction of polyatomic interferences compared to static GD sources

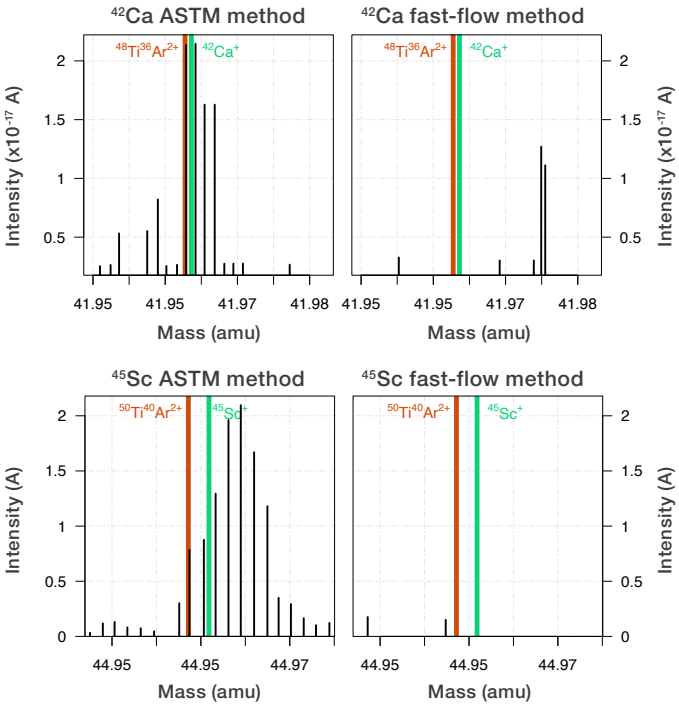


Figure 3. Typical mass spectrum of ^{42}Ca and ^{45}Sc during the analysis of high purity Ti. (Left) ASTM F1710-08 method using static source. (Right) Fast-flow method using the Element GD Plus GD-MS. Overlapping isobaric interference from ^{48}Ti^{36}Ar^{2+} and ^{50}Ti^{40}Ar^{2+} is suppressed by the fast flow source.

Case study

Elemental analysis of high purity 6N copper

The Element GD Plus MS provides a routine, reliable and straightforward solution for ultra-trace analysis of high purity copper. Detection limits of <0.01 µg/g in 5N or 6N copper samples are easily achieved.

- Fast sample turn-around of 5 samples per hour guarantees rapid feedback to production
- Capacity to analyze ~120 samples per day
- Automatic resolution switching (within 1 s) enables the routine use of optimum mass resolution for the elimination of matrix induced interferences

Table 1. Results obtained from repeat analysis of a 6N Cu sample at multiple spots

Element	Typical LoD [µg/g]	Obtained LoD [µg/g]
Ag	<0.01	0.005
As	<0.01	0.001
Bi	<0.01	0.0003
Fe	<0.01	0.001
Pb	<0.01	0.0004
S	<0.1	0.03
Sb	<0.01	0.001
Se	<0.01	0.002
Te	<0.01	0.001

Trust in results by high mass resolution

The simplicity of high-resolution ICP-MS allows the most advanced performance, without compromising on straightforward and reliable method development.

Indisputable analytical results

- The Element GD Plus GD-MS provides interference free measurements, resulting in simple linear calibration curves for quantification
- Three fixed resolution settings (300, 4,000, 10,000), with switching times of <1 s, ensure optimum conditions to reliably remove spectral interferences
- Fast flow source for lowest levels of polyatomic interferences creates clean spectra and facilitates full interference removal without manual user interaction

Maximum level of selectivity

- Any combination of resolution settings can be performed within a single analysis

Excellent abundance sensitivity

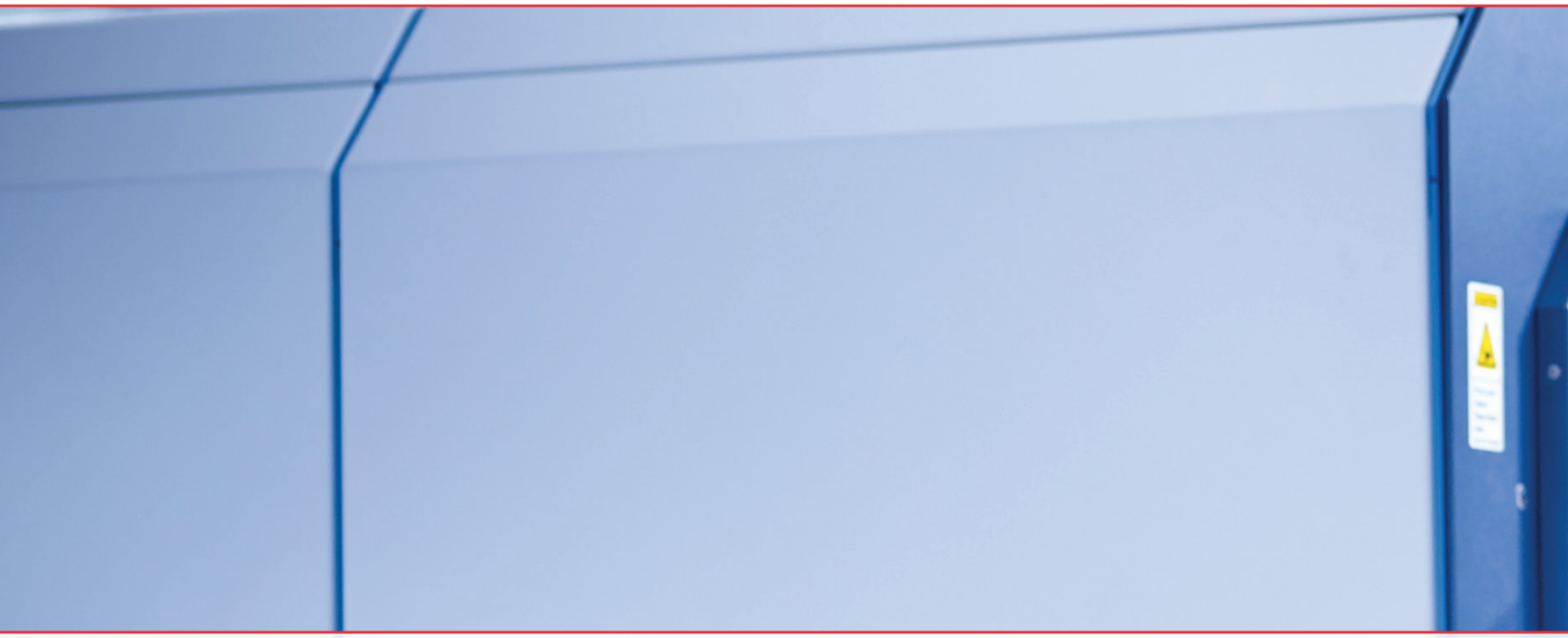
- Minimum contribution of high matrix signals on neighboring analyte peaks due to filter lens

Robust results

- The fixed-slit design guarantees maximum stability and reproducibility
- Medium resolution (R=4,000) removes the majority of interferences
- High resolution (R=10,000) used routinely to remove those few isotopes that would otherwise require manual or mathematical user interaction
- The fixed-slit design is robust against wear ensuring long-term reproducibility

Minimum matrix effects for straightforward standard RSF quantification

- Due to the fast-flow GD source the formation of polyatomics is low and trimeric interferences are virtually non-existent, giving clean spectra that are easy to integrate



Case study

Resolving ^{103}Rh from $^{63}Cu^{40}Ar$ interference in high resolution

^{103}Rh and $^{63}Cu^{40}Ar$ have a mass difference of 0.13%. To resolve Rh from the CuAr requires a mass resolution of >7,600.

- High resolution mode provides a mass resolution of 10,000
- Capability to clearly resolve ^{103}Rh from the $^{63}Cu^{40}Ar$ interference

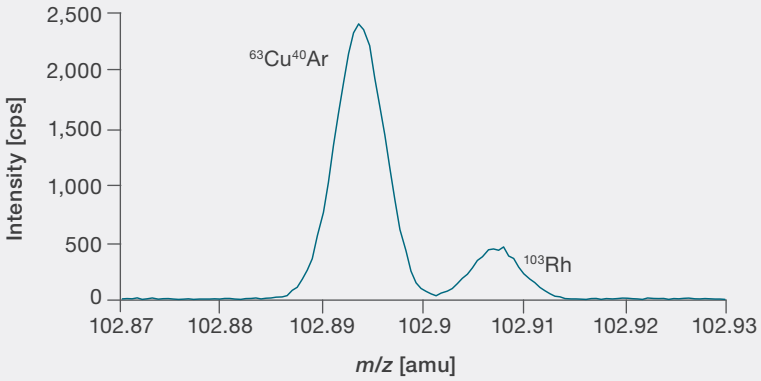


Figure 4. Resolving ^{103}Rh from $^{63}Cu^{40}Ar$ interference in high resolution (R=10,000). Sample containing 600 ppm Cu and ca. 0.16 ppm Rh.

Case study

Resolve ^{67}Zn and ^{60}Ni in a Cu matrix

Zinc and nickel are important minor and trace impurities that need to be monitored in high purity copper samples (ASTM F2405).

High abundance sensitivity allows ^{67}Zn, ^{68}Zn and ^{60}Ni to be analyzed without background in a copper matrix.

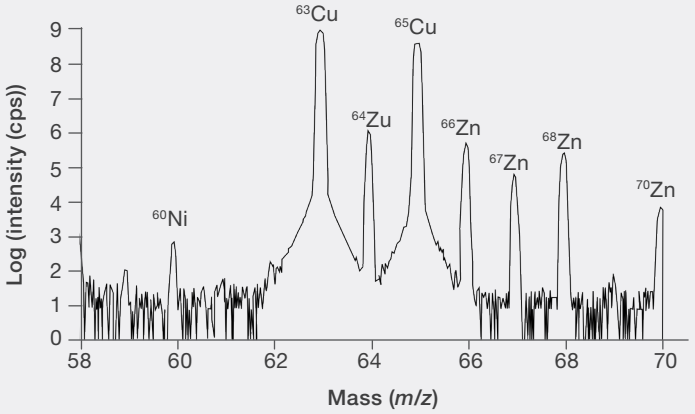


Figure 5. Resolving ^{67}Zn and ^{68}Zn in a copper matrix. Copper sample contains ca. 100 ppm of Zn and ca. 0.5 ppm of Ni.

Depth profiling with nanometre resolution

Depth profiling is an important tool for elemental analysis of coatings and the assessment of element diffusion across layers.

- Depth resolution from nanometers to hundreds of micrometers
- Determining concentrations of all elements from sub-ppm to 100% without the need for calibration
- Enhanced depth resolution by pulsed mode operation
- Fast flow allows improvement of the transport efficiency of ions to the mass spectrometer and, consequently, higher analytical sensitivity
- Flexible anode diameter for advanced depth profiling applications
- Grimm GD-based ion source creates flat crater shapes on the sample, ideal for depth profiling
- Sputter rates can be adjusted for bulk analysis or depth profiling
- High signal/noise ratios

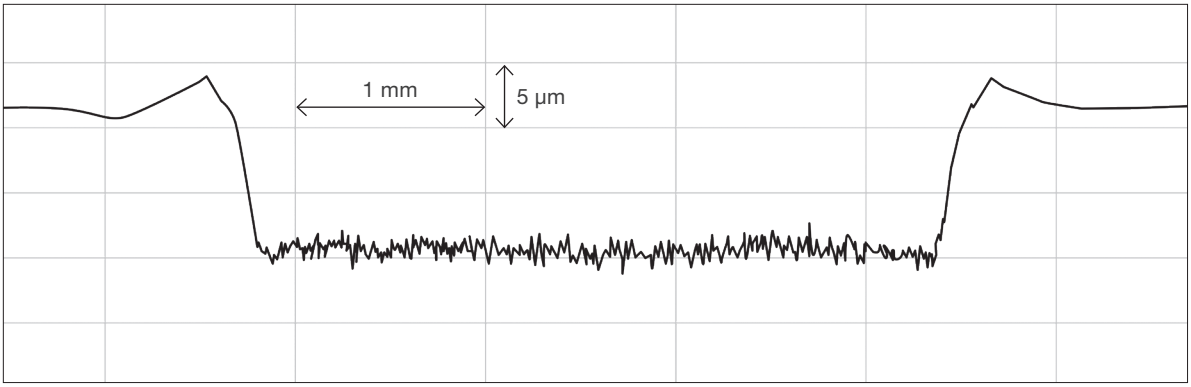


Figure 6. Typical crater shape of a depth profile on a copper sample.

Case study

Depth profiling of solar cell silicon

Materials for photovoltaic applications are sensitive to impurity concentration. Ppm levels impurities in the silicon feedstock and ppb levels impurities in the silicon wafer dramatically affect the electrical properties of the final solar cell.

- Fast flow and wide dynamic range of the Element GD Plus GD-MS offers the best sensitivity and lowest limits of detections necessary for analysis of solar cell silicon
- 0.5 µm depth resolution
- Synchronous analysis of B, P, Ti, Fe and Cu impurities in multicrystalline p-type silicon samples
- 30 seconds acquisition time

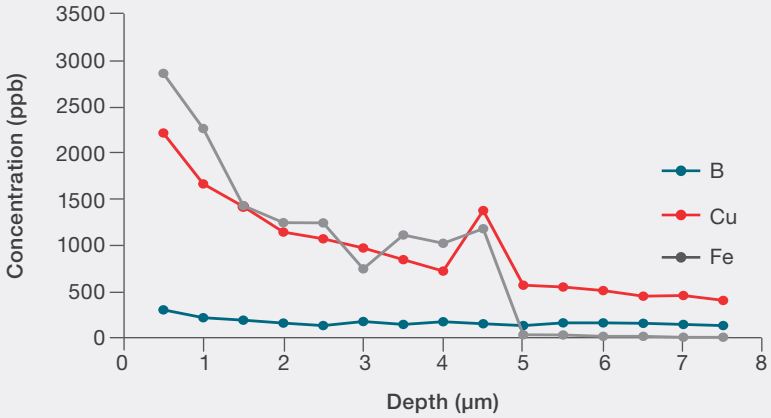


Figure 7. B, Fe and Cu concentrations along the sputtered depth of sample.
Sabatino *et al.*, J. Anal. At. Spectrom., 2014, 29, 2072.

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