

DEVELOPMENT AND APPLICATION OF AN ICP ORTHOGONAL ACCELERATION TIME-OF-FLIGHT MS

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ICP-MS is a powerful technique that provides almost complete elemental and isotopic analysis for a diverse range of samples. The ICP-MS typically provides detection limits at sub parts per trillion levels for a wide range of elements, up to 7 orders of magnitude in linear working dynamic range and precision of typically around 1%. Since the release of the first commercial ICP-MS instrument in the early 1980's, the technique has gained wide acceptance in a vast range of disciplines including the analysis of environmental, biological, nuclear, geological and industrial samples.

Until now the most common commercially available ICP-MS instruments have utilized quadrupole mass analyzers which can be considered as a mass filter analyzer. This characteristic of the quadrupole mass spectrometer has serious limitations for elemental analysis due to its sequential nature. The speed limitation of quadrupole based ICP-MS instrumentation is responsible for a number of weaknesses of the technique including limited precision at high speed and for a large number of elements, low sample throughput for full mass range analysis and limited capability in handling fast transient signals for multi-element analysis.

Currently emerging analytical techniques, such as single shot laser ablation analysis, multi-element ETV ICP-MS of single solid particles, direct powder introduction ICP-MS and direct sample insertion ICP-MS all produce sample residence times in the plasma of less than a second or even the order of milliseconds. Under these conditions scanning mass analyzers, such as quadrupoles, are limited to the measurement of just a few masses.

An ICP Time-of-Flight Mass Spectrometer (ICP-TOFMS) overcomes many of the major limitations associated with scanning quadrupole based ICP-MS instrumentation. In a time-of-flight mass analyzer, all ions that contribute to the mass spectrum are accelerated into a flight tube at the same time, and the mass is related to the time taken to reach the ion detector.

The true advantage of a time-of-flight mass spectrometer is high speed and simultaneous sampling mass analysis. The entire mass spectrum can be collected in about 30 μ s, with 30,000 full mass spectra collected per second. Whilst the entire mass spectrum is collected in less than 30 μ s, all ions detected during this time are sampled from the source simultaneously, i.e., there is no time skew between masses during plasma sampling. This high rate of spectral acquisition and simultaneous sampling, inherently overcomes a majority of the limitations of a quadrupole based spectrometer and ultimately leads to higher sample throughput, improved precision at high speeds and for ratio analysis, and provides true multi-element transient analysis.

This new instrument incorporates an orthogonal acceleration time-of-flight mass spectrometer. The continuous ion beam is chopped by the orthogonal accelerator and a push out pulse supply is coupled to the accelerator for providing repetitive push-out voltages at a frequency of 30kHz. The ion packets that are sliced out of the beam then travel within the field free space towards the SMARTGATE ion blanker. Orthogonal accelerator parameters are set to enable temporal-spatial focussing at the SMARTGATE ion blanker, so that iso-mass ion packets are resolved in time. Any ion packets of unwanted species are ejected from the direction of travel by supplying pulsed voltages onto the deflection plates of the SMARTGATE. The ions to be measured are let through SMARTGATE and travel further down the field free space, to enter the ion reflectron. The ion reflectron increases the resolution of the mass spectrometer by means of temporal-energy focussing. After reflection, the ions travel within the field free space towards the discrete-dynode detector.

The fact that only a single mass channel can be measured at any one time with a quadrupole instrument means there is always a compromise that needs to be made between mass range, detection limits, precision of the result, and the measurement time. If the required analysis is at detection limit levels or requires high precision, either the number of masses measured must be limited or the overall measurement time must be increased. Whereas, if a large number of elements must be determined in a sample and sample volume is limited or speed of analysis is an issue, the achievable detection limit and precision of the result must be sacrificed. An ICP-TOFMS does not suffer from this compromise. As all masses are measured simultaneously, the required measurement time, achievable detection limits and precision of the result remain the same regardless of the number of masses that need to be measured.