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Innovation in the use of Fixed Slits to Overcome the Issues of Slit Lifetime and Lack of Application Flexibility

Introduction

High Resolution Magnetic Sector ICP-MS is established now as the go to method for unambiguous determinations of trace concentrations in complex matrices. The ability to physically separate the mass of an analyte from the interfering polyatomic species makes the technique robust and trustworthy for developing methods of analysis in a research or routine laboratory. This characteristic performance is achieved by physically restricting the ion beam with a slit on both the entrance and exit of the mass spectrometer itself. Until recently, there have been two approaches to this implementation; variable slits where two perfectly parallel blades are precisely controlled to impose a slit width in the path of the ion beam; and fixed slits laser cut into a thin sheet of metal and moved into the beam line.

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The variable slit has the advantage of flexibility so the optimum slit widths can be chosen without compromising the analysis, the blades can also be fabricated from hardened material to a very high precision giving a long lifetime for the source slit which experiences high levels of ion erosion from the argon plasma. The disadvantage of the variable slit is the reproducibility of the slit width which can make switching between resolutions in routine analysis less desirable.

The traditional fixed slit has the advantage of good reproducibility of resolution settings when changed in an automated run. However, each different resolution requires a new slit which can present issues for slits moved across ion beam in the plane of the spectrometer. Also, to fabricate a slit to micron tolerances requires that very thin material is used which dramatically reduces the lifetime of the source slit in normal use.

This application note will describe a new way of using fixed slits that maintains the high reproducibility of the technique whilst over coming the disadvantages of short lifetime and closely approaches the flexibility seen with variable slits.

Long lifetime

The lifetime of the slits is usually determined by the source slit which is exposed to the full beam of ions from the plasma. This is especially intense with dry sample introduction systems where water is not present which reduces the argon ion intensity. At the slit focus point the ion beam is about 1 mm high so a slit drive mechanism has been designed which would allow multiple slits, each with several millimetres of available width to be moved vertically through the plane of the ion beam in the spectrometer. The carriage assembly is shown in Figure 1 and one possible slit plate shown in Figure 2.

With this design, as one part of the slit becomes eroded by the ion beam, which can take a few weeks to a few months depending on use, a different part of the same slit can be chosen thus extending the time between slit changes significantly.

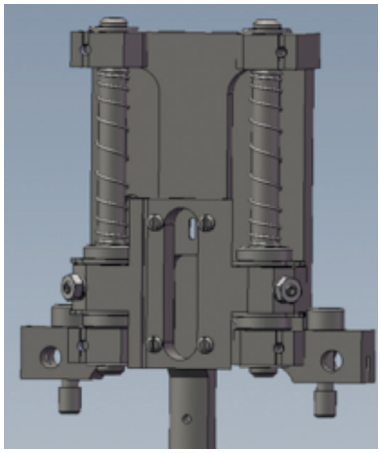

Figure 1: CAD model of slit movement assembly

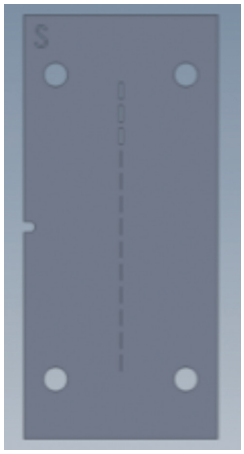

Figure 2: Slit mask showing the use of multiple slits which can be for different resolutions or longer lifetimes for a particular resolution as required.

The slit at the collector side of the mass spectrometer does not experience the high intensity beams exposed to the source slit so it is not required to have slits which are much longer than the height of the ion beam. This allows for more different width slits on the collector plate compared to the source plate leading to more available resolutions by combining source and collector positions appropriately.

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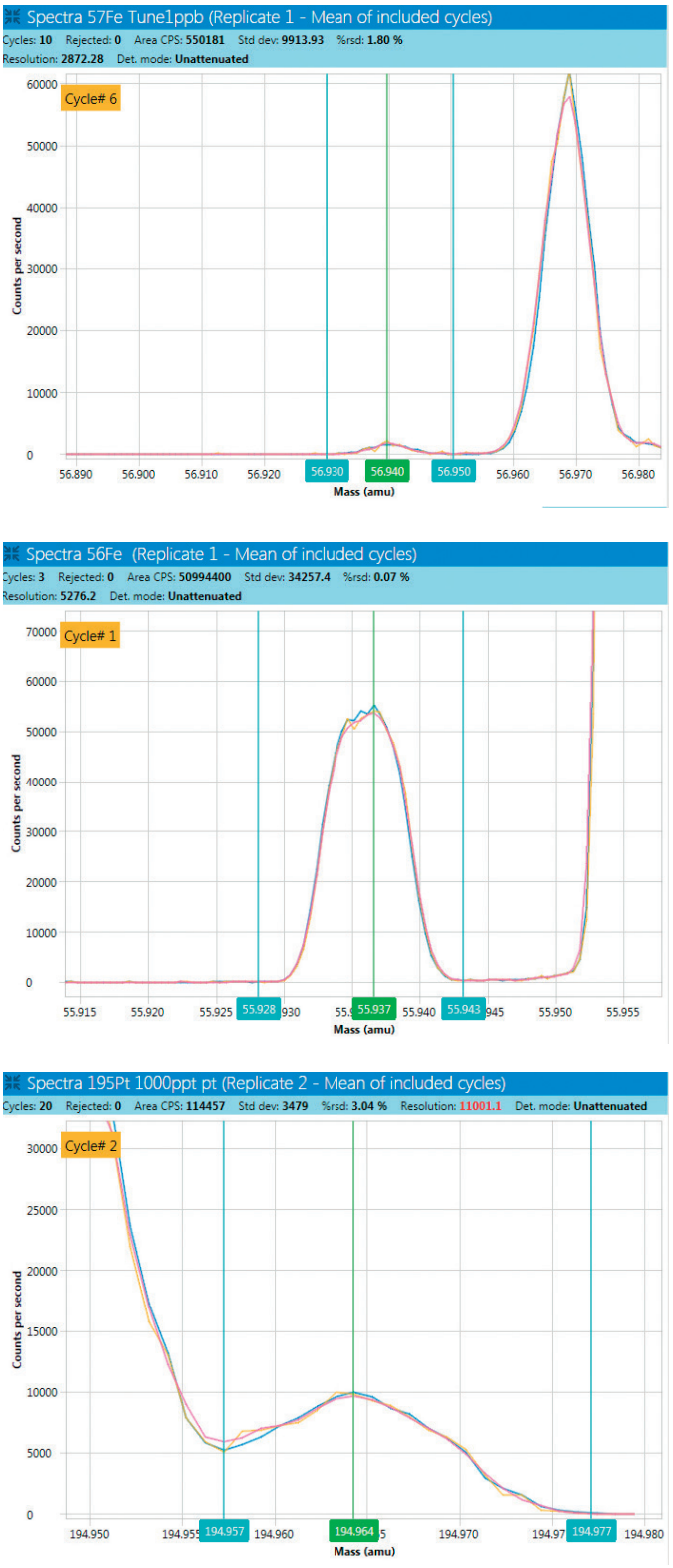

Figure 3: Charts from Nu Quant showing the resolution capability of Attom with fixed slits. Examples show ^{57}Fe separated from argon hydroxide with the mimimum recommended resolution, ^{56}Fe fully resolved to baseline from the nearby large argon oxide interference and ^{195}Pt resolved from hafnium oxide and hydroxide (requiring >10,000 resolution).

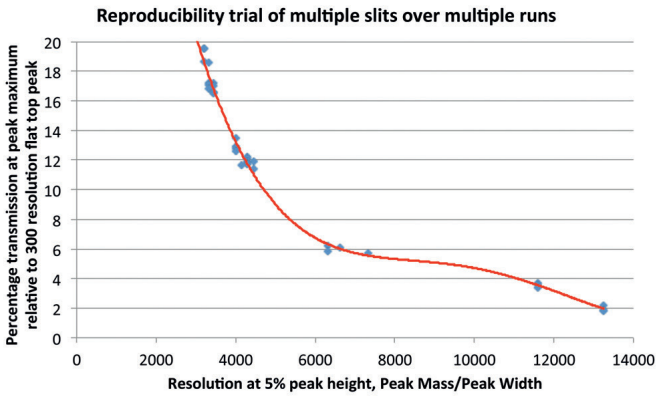

Figure 4: Graph showing the transmission of the ion signal relative to low resolution flat top peaks for a variety of slit masks chosen for different high resolutions.

Flexibility

The ability to define multiple slit widths on both the source and collector plates gives the Attom a level of flexibility that approaches the previous variable slits. As standard 3 slit widths are used on the source slit and 5 on the collector which allows resolutions from 300 Rp to >10,000 Rp with at least 4 different resolutions in between so the optimum resolution can be found for each analyte interference pair. Figure 3 shows a range of achieved resolutions for isotopes with interferences and Figure 4 shows the transmission curve using different resolutions for a range of analytes. As the slit plate can be replaced very easily, even after installation and the slits are customisable, it is possible for a user to choose a different set of source and collector slits to match their needs for particular resolutions or lifetime of a particular slit size.

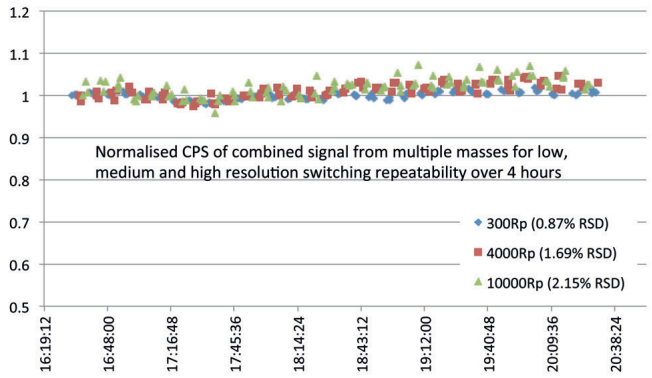

Figure 5: Graph showing the reproducibility of ion signal when switching resolutions during a batch of samples.

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Reproducibility

The primary aim of the new slit design on Attom was to make changing resolutions fast and extremely reproducible. Figure 5 shows the reproducibility of switching between different resolutions over 4 hours and Figure 6 shows the reproducibility of peak position for a variety of masses at 4000 Rp when switching over more than 10 hours.

It should be noted here that this data was obtained without any software correction of the peak position during the run and therefore shows the intrinsic stability of the hardware. The use of vertical slit movement and a precision engineered laser cut slit plate on the slide assembly in Figure 1 gives a high confidence of recovering the peak position as shown in this data.

Conclusion

The new fixed slit design on the Attom achieves high levels of reproducibility for both resolution and peak position. This is achieved without compromising the Attom's flexibility to choose the optimum resolution for different applications and providing the longest possible times between replacements of consumable parts.

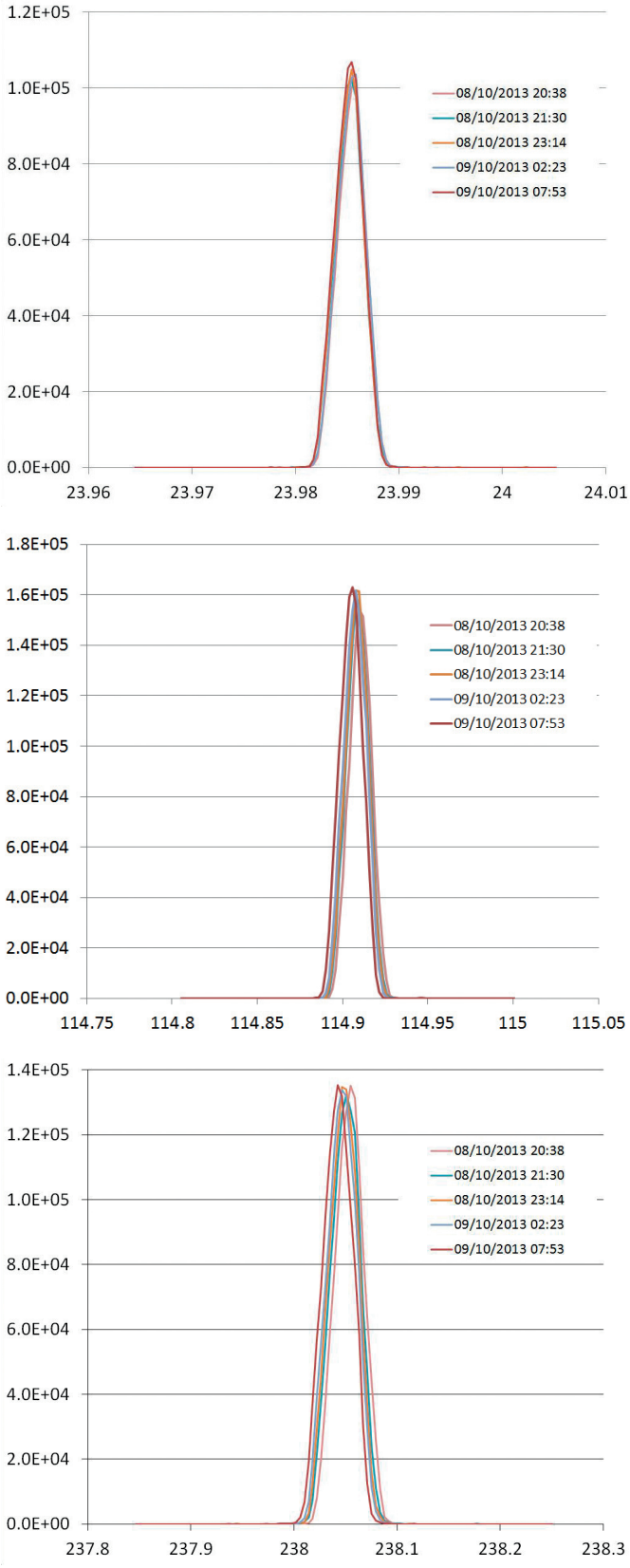

Figure 6: Charts showing the stability of peak position and reproducibility of resolution and peak shape for ^{24}Mg, ^{115}In and ^{238}U over more than 10 hours running samples with mixed resolutions.