Smart Notes

LA-ICP-MS for U-(Th)-Pb geochronology: Which analytical capability is right for my laboratory?

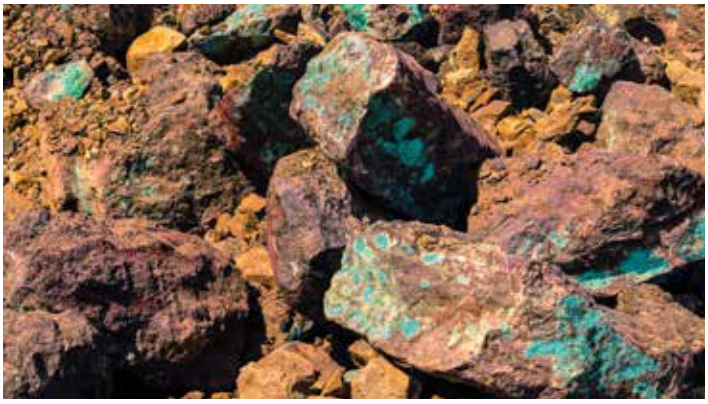
One of the most important dating techniques available in geosciences is U-(Th)-Pb dating by LA-ICP-MS. It exploits the natural decay of radioactive U and Th isotopes into stable Pb isotopes in zircon and other common (U-Th)-bearing minerals. The coupling of laser ablation (LA) to inductively coupled plasma mass spectrometry (ICP-MS) has developed into the most commonly applied technique for measurement of U-(Th)-Pb ages.

A wide variety of ICP-MS is available, differentiated by mass analyzer and detection system. U-(Th)-Pb isotopes are routinely analyzed on the entire range of Thermo Scientific™ ICP-MS instruments in many laboratories worldwide.

If you are interested in adding U-(Th)-Pb dating capability to your laboratory three options are available:

- Quadrupole (Q)-ICP-MS
- High Resolution (HR)-ICP-MS and
- Multicollector (MC)-ICP-MS.

This Smart Note will clarify which option is the best option for you.



ThermoFisher SCIENTIFIC

What are the advantages of LA-Q-ICP-MS?

In U-(Th)-Pb geochronology ^{204}Pb, which can be used to correct for "common" (i.e. non-radiogenic) lead, has an isobaric interference in ^{204}Hg, which can be overcome by using the the collision/reaction cell (CRC) system of the Thermo Scientific™ iCAP™ TQ ICP-MS. Ammonia gas in the CRC is effective at removing mercury from the ion beam through a charge transfer reaction, leaving the Pb ions unaffected (see application note 44387)[1]. It is as straightforward to set up the reaction gas triple quadrupole analysis as it is to use a conventional single quadrupole ICP-MS, with only limited training.

The iCAP TQ ICP-MS has been developed with simplicity of operation at the forefront. Its small footprint, lightweight and robust hardware design is complemented by easy-to-use Thermo Scientific™ Qtegra™ Intelligent Scientific Data Solution (ISDS™). Software plug-ins integrate most current laser ablation systems with ISDS.

What are the advantages of HR-ICP-MS?

The sensitivity offered by the double-focusing, magnetic sector Thermo Scientific™ Element™ Series HR-ICP-MS is better by ca. one order of magnitude than Q-ICP-MS. This results in improved final precision on isotopic ratios. This however comes at a cost, the HR-ICP-MS being 1.5 to 2.0 times more expensive to buy than TQ-ICP-MS. The CRC system is not available for the Element Series HR-ICP-MS, hence ^{204}Hg cannot be removed but can be subtracted from the measured 204 signal by monitoring ^{202}Hg.

The Element XR HR-ICP-MS with the Jet Interface had a measured ^{238}U signal ca. 20 times more intense than when measured by TQ-ICP-MS (Figure 1 and see also reference n. 5).

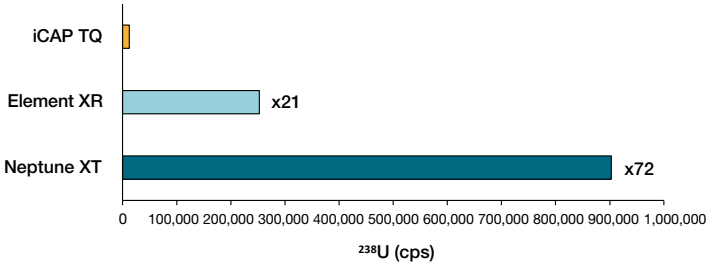


Figure 1. Number of ^{238}U counts detected for a 35 µm diameter, 3 J cm^{-2} 7 Hz repetition rate, 30 second duration ablation of the 91500 reference zircon with three Thermo Scientific ICP-MS in the demo facility in Bremen, Germany. The laser ablation system used was a Teledyne Photon Machines™ Analyte G2™ 193 nm excimer with a HelEx™ ablation cell.

The enhanced sensitivity of LA-HR-ICP-MS results in better age resolution compared to LA-Q-ICP-MS, i.e. a lower final uncertainty on the $^{207}Pb/^{206}Pb$ age (Figure 2) using the same laser spot-size, energy and repetition rate. Alternatively, the area ablated can be significantly reduced, the ^{238}U signal intensity of a 35 µm spot with LA-Q-ICP-MS being equivalent to a 8 µm spot with LA-HR-ICP-MS. This results in a substantial improvement in terms of spatial resolution.

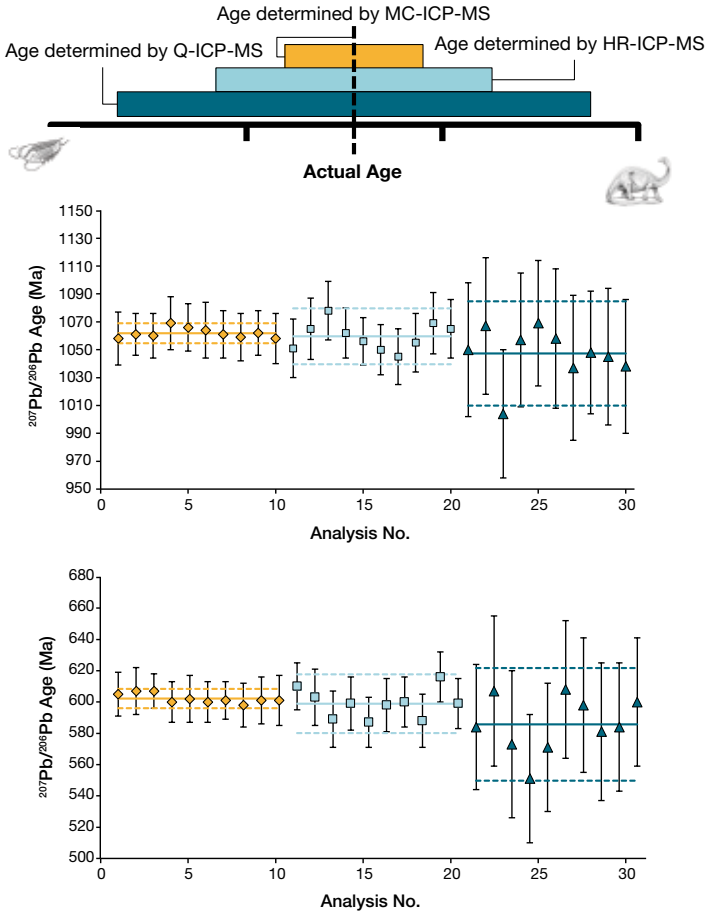


Figure 2. $^{207}Pb/^{206}Pb$ Age determination for 10 ablations (35 µm diameter, 3 J cm^{-2} 7 Hz repetition rate, 30 second duration) of A. 91500 and B. GJ-1. Internal error bars 2SE, external error bars 2SD. All data processing was carried out in Iolite™ v3.63.

The increased sensitivity of LA-HR-ICP-MS is effectively used to mitigate laser-induced inter-element (or down-hole) fractionation (LIEF), a major limiting factor in LA-ICP-MS U-Pb dating which must be corrected to avoid systemic inaccuracies[3]. LA-HR-ICP-MS can use a lower laser fluence, repetition rate and measurement duration than LA-Q-HR-ICP-MS in order to reduce the depth of the ablation crater hence limit the impact of LIEF.

Are there any advantages to LA-MC-ICP-MS for LA U-(Th)-Pb geochronology?

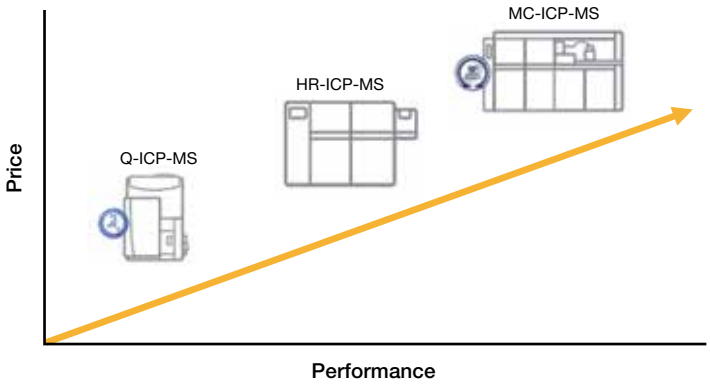
Similar to the Element Series HR-ICP-MS, the Thermo Scientific™ Neptune™ XT MC-ICP-MS is a double-focusing, magnetic sector ICP-MS not equipped with a CRC. Rather than a single detector, the Neptune XT MC-ICP-MS uses multiple collectors on the focal plane of the magnetic sector for simultaneous detection of each isotope. Detectors can either be a secondary electron multiplier (SEM), or Faraday cups: a variety of tailored detector packages are available for U-(Th)-Pb analysis on the Neptune XT MC-ICP-MS (Table 1).

Table 1. Neptune XT MC-ICP-MS U/Pb cup configuration using Thermo Scientific™ 10^{13} Ω Amplifier Technology™. Multi-ion counting packages are also available.

CDD1	CDD2	L4	L3	L2	L1	C	H1	H2	H3	H4
^{202}Hg	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb	-	-	-	^{232}Th	^{235}U	^{238}U
SEM	SEM	10^{13} Ω	10^{13} Ω	10^{11} Ω	-	-	-	10^{11} Ω	10^{11} Ω	10^{11} Ω

The Neptune XT MC-ICP-MS takes advantage of the Jet Interface to achieve the highest sensitivity available in ICP-MS[4]. The best isotope ratio precision of the three available instruments can be obtained for identical laser conditions (Figures 1 and 2) or the amount of material ablated can be reduced. For zircons, LA-MC-ICP-MS can combine U-(Th)-Pb geochronology with complementary high precision Hf isotope ratio measurements, the latter measurements requiring the superior precision of a multicollector instrument.

LA-MC-ICP-MS offers the best possible performance, but this must be balanced against the extra cost, footprint, training, and effort required to cross-calibrate the multiple independent detectors of the MC-ICP-MS.



References

1. Asogan D., 2018. Using triple quadrupole interference removal to improve data quality in laser ablation ICP-MS for geochemical applications. *Thermo Fish. Sci. Appl. Note 44387.*
2. Triple Quadrupole ICP-MS or High Resolution ICP-MS? Which Instrument is Right for Me? *Thermo Fish. Sci. Smart. Note 43402.*
3. Schaltegger U., Schmidt A., Horstwood M.S.A., 2015. U-Th-Pb zircon geochronology by ID-TIMS, SIMS, and laser ablation ICP-MS: recipes, interpretations, and opportunities. *Chemical Geology*, **402**, 89-110.
4. Craig G., Managh A.J., Stremtan C., Lloyd N.S., Horstwood M.S.A., 2018. Doubling Sensitivity in Multicollector ICPMS Using High-Efficiency, Rapid Response Laser Ablation Technology. *Analytical Chemistry*, **90**, 11564-11571.
5. Pullen A., Ibáñez-Mejia M., Gehrels G. E., Giesler D., Pecha M. 2018. Optimization of a laser ablation-single collector-inductively coupled plasma-mass spectrometer (Thermo Element 2) for accurate, precise, and efficient zircon U-Th-Pb geochronology. *Geochemistry, Geophysics, Geosystems*, **19**. https://doi.org/10.1029/2018GC007889.

Authors

Grant Craig, Laura Bracciali and Nicholas Lloyd, Thermo Fisher Scientific, Bremen, Germany.

Find out more at **thermofisher.com/ICP-MS**

SN30581-EN 0320C