Living up to the Hype(-rion)! – observations on ion microprobe geochronology using a high-brightness oxygen plasma source

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The recent introduction of a high-brightness RF plasma oxygen ion source (Hyperion H201, Oregon Physics) to large geometry secondary ion mass spectrometers (e.g. CAMECA IMS1280/1300) has increased the range of available primary beam options compared to the several decades old technology of the duoplasmatron it replaces. Notably, the new source provides considerably higher beam density (ca. 10x and 3x for O$^-$ and O$_2^-$ respectively), which in principle allows for higher spatial resolution and/or shorter analysis times, coupled with unprecedented long-term beam stability.

Incorporating the RF plasma into both conventional spot analysis and ion-imaging geochronology routines at the NordSIMS facility has, however, revealed that the source upgrade has consequences for data-acquisition and data reduction strategies, which need to be modified in order to avoid degradation in precision. The most significant difference using the new source for spot analyses is the significant change in aspect ratio (width/depth) of the analysed volume. During a comparable length analysis, a three times brighter O$_2^-$ primary beam (still favoured for U-Th-Pb geochronology) will sputter a three times deeper crater that is half the width of a comparable intensity duoplasmatron beam, an effective aspect ratio change of six times, introducing “down-hole” inter-element and, to a lesser degree, isotope fractionation effects that SIMS has largely been free of. Depending on the target matrix, this can have a marked effect on the within-run ratio evolution during an analysis, particularly the inter-element ratios Pb/U and UO$_{2n}$/U required for full U-Pb geochronology, with standard error of the mean values several times higher than counting statistics, compared to analyses with the lower beam density of the duoplasmatron where s.e. mean commonly closely approaches Poisson counting statistics during a ca. 10 minute analysis. In line with previous observations [1], some improvements can be made by using a Pb/UO vs. UO$_2$/UO calibration scheme instead of Pb/U vs. UO$_{2n}$/U, but clearly this is not the complete answer. Shortening analyses via fewer cycles in a peak-hopping routine also means smaller $\sqrt{n}$, affecting s.e. mean; lower integration times can be introduced to permit more cycles, but magnet settling times between peak jumps cannot be reduced in proportion, so the duty cycle is less efficient.

Strategies developed to mitigate this degradation and take full advantage of the new RF source include: 1) rastering of critically focused primary beams to retain high aspect ratio (at the expense of improved spatial resolution); 2) use of a defocused aperture-projected (Köhler-mode) primary
beam (effectively lower beam density); 3) modelling of within-run ratio evolution based on standard analyses in a manner similar to that employed by laser ablation methods [2]; and/or 4) introduction of multicollection capabilities [3] to increase duty cycle efficiency in a shorter analysis. Ultimately, the choice of which method(s) to use will depend upon the goal of a specific project.
