

Measuring isotopic compositions of fluid inclusions under cryogenic conditions with the new CAMECA NanoSIMS-HR

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The NanoSIMS is a high spatial resolution microprobe, coupled with a high sensitivity Secondary Ion Mass Spectrometer (SIMS). In 2024, CAMECA introduced the new NanoSIMS-HR [1] as the successor of the NanoSIMS 50L. It offers several improvements compared to the previous version. Notably: (1) A more accurate imaging capability thanks to an improved Cs⁺ source improving the lateral resolution down to ≤ 30 nm and thus dramatically limiting lateral dilution of isotopic and elemental composition of the measured surface. (2) A more accurate depth profiling capability thanks to a primary beam energy ranging from 16 keV to 2keV, improving the ultimate depth resolution down to 12 nm/dec. (3) A capability to introduce atmosphere sensitive samples (such as extraterrestrial material or highly reactive battery components). (4) A capability to image elemental and isotopic compositions of fluid inclusions with a cold stage.

Fluid inclusions have been of particular interest in many geological studies for a long time, though previous techniques, such as GC-MS or LA-ICPMS, were mostly focusing on molecular and elemental compositions, and often required large enough inclusions to collect material. The unique in-situ capabilities of the NanoSIMS, combined with the new cold stage, allow the analysis of μm -sized inclusions and with sufficient sensitivity to reveal isotopic ratios of the fluid contained in each inclusion. Using specifically designed LN₂ cold stage and sample-holders, the sample is cooled down to -140°C, freezing the fluid inside the inclusions and allowing their analysis as solid material, even within the vacuum of the SIMS analysis chamber.

Aqueous inclusions from various geological materials have been successfully analyzed for their elemental and isotopic compositions. In particular, D/H and ¹⁸O/¹⁶O ratios have been determined in ~ 4 μm fluid inclusions from quartz samples with a precision of 16‰ and 5‰ (1 S.D.) respectively.

[1] Weber, P. K. et al. (2024), *Analytical Chemistry*, 96 (49), 19321-19329.