

Sr isotopic compositions of ultra-deep inclusions in diamonds: Implications for mantle chemical structure and evolution

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Recent models of mantle convection combined with seismology have caused a paradigm shift in Earth Sciences away from two-layered convection of the mantle, towards models that involve convective stirring throughout most of the mantle depth. Such models are now being supported by a variety of new geochemical data. This makes the study of our only samples of the lower mantle, ultra-high pressure inclusions in diamonds, imperative as one of the few ways of directly testing predictable outcomes of these models.

To do this we have applied ultra-low blank Sr isotope chemical techniques along with carbon isotope analyses to a suite of diamonds from the Rio Soriso, Mato Grosso, Brazil to investigate the isotopic characteristics of the lower mantle. The suite of diamonds were kindly supplied by Dr F. Kaminsky and contain inclusions of Mg-silicate perovskite (MgSiO₃), Ca-silicate perovskite (Ca-Pv; CaSiO₃) and ferropericlasite, among other minerals. Ca-Pv inclusions contain several hundred to >1000 ppm Sr making it possible to analyse small inclusions of this mineral for their Sr isotopic composition, hence providing the first reliable Sr isotope determinations for the lower mantle environment. Our technique also allows determination of trace element compositions, including rare earth elements.

Two Ca-Pv inclusions have Sr isotopic compositions significantly less than the model "Primitive Mantle" ⁸⁷Sr/⁸⁶Sr composition (~ 0.7045) suggested for the lower mantle in two-layer convection models. The values obtained overlap with the MORB compositional spectrum which is taken as reflecting the long-term depletion history of the upper mantle. We interpret the Sr isotope results to indicate that the lower mantle, at the depths sampled by inclusions within diamonds, is not distinct from the upper mantle in terms of its Sr isotope composition. Carbon isotope data for these ultra-deep diamonds will also be presented to examine differences between "shallow" mantle carbon and ultra-deep carbon.

Mass bias: A comparison of solution and laser ablation MC-ICPMS

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The development of in-situ isotope ratio measurements using LAM-MC-ICPMS has proceeded steadily over recent years. To date the most widely used technique is the analysis of Hf isotopes in zircon and this application is now undertaken in many laboratories around the world. Other radiogenic isotope systems (e.g. Sr, Nd, Os, Pb) have been successfully measured in a variety of minerals but despite the demonstrated significance of spatially resolved measurements, these in-situ methods remain relatively restricted in their application. The main limitations (in accuracy and precision) are the trace-level abundance of the elements of interest and the magnitude of isobaric overlap corrections related to parent/daughter ratios. In-situ analysis of 'non-traditional' stable isotopes has not progressed as far as the radiogenic systems and this is mainly due to a lack of understanding of the processes that contribute to isotopic fractionation during ablation and in the plasma.

Recent studies have demonstrated that the origin of isotopic fractionation in LAM-MC-ICPMS is the result of a combination of laser- and ICP-induced fractionation. Whereas internal normalization using stable isotope pairs is able to account for the effects of these processes for radiogenic systems, the in-situ analysis of mass dependent stable isotopes requires careful standard-sample bracketing techniques using matrix-matched materials. The isotopic compositions of different aerosol particle size fractions of Cu metal show an enrichment of up to 0.5 per mil of the lighter ⁶³Cu isotope in the sub-250 nm particles. Isotopic fractionation is further enhanced by preferential ionization of the lighter isotopes from incompletely vaporised particles in the ICP. Analysis of Mg isotopes in olivine (Fo 92) indicates that there is no change in particle size distribution with ablation time and points to the influence of the ICP on isotopic fractionation.

The aims of this study are to provide a framework to understand the parameters and processes that control mass bias in the ICP, especially the differences between solution (wet) and laser (dry) plasma. A series of experiments has been carried out to investigate the contribution of plasma power, extraction voltage, gas flow, torch position, gas composition (Ar±He), sample matrix, and plasma loading on mass bias. Results will be presented for light, middle and heavy mass isotopic systems (e.g. Mg, Cu, Sr, Hf).