ATOM-PROBE MEASUREMENTS OF METEORITIC NANODIAMONDS AND TERRESTRIAL STANDARDS

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Introduction: The origin of meteoritic nanodiamonds has been puzzling since their identification in 1987. A presolar origin has been inferred from anomalies in the trace nuclides, most notably Xe-HL [1]. However, bulk measurements of the major element C and the minor element N yield approximately solar isotopic ratios [2–4]. If a presolar component is present, it is either diluted by a significant fraction of isotopically normal material or coincidentally has averages close to the solar system values over millions of grains. The primary obstacle to directly measuring the $^{12}C/^{13}C$ ratio of individual nanodiamonds has been the ~3 nm mean size of these grains [5]. We present new data from the novel application of atom-probe tomography to the study of nanodiamonds from the meteorite Allende. This technique has sub-nm spatial resolution and ~50% atomic detection efficiency [6].

Experimental: In atom-probe tomography, a ~100 nm radius needle-shaped tip is field-evaporated, atom-by-atom, using high voltage and thermal pulses from an ultraviolet laser. The locations and mass-to-charge-state ratios of ions are measured using time-of-flight mass spectrometry and a microchannel plate detector. These data are combined into a 3-D reconstruction of the sample volume. Allende nanodiamonds or terrestrial detonation diamond standards were sandwiched between layers of sputter-deposited Pt and prepared into tips using FIB (Focused Ion Beam). Analyses were conducted using the Cameca LEAP (Local Electrode Atom-Probe) 4000X Si at Northwestern University.

Results: The $^{12}C/^{13}C$ peak ratios for ten tips containing standard terrestrial nanodiamonds have a mean value of 46 with a standard deviation of 21 (terrestrial = 90). Ten tips prepared using an Allende acid residue have a mean $^{12}C/^{13}C$ peak ratio of 61 with a standard deviation of 22. In several tips, we observe distinct C clusters with sizes similar to those of individual nanodiamonds. The $^{12}C/^{13}C$ peak ratios of seven such clusters from four Allende tips range from 66 to 152, albeit with large errors. Instrumental effects such as $^{12}C^{1}H^{+}$ interference at the $^{13}C^{+}$ peak and detector pileup are both expected to lower the measured ratio; we are pursuing means to quantify and correct for such effects.

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