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Characterization of Meteorites by Focused Ion Beam Sectioning: Recent Applications to CAIs and Primitive Meteorite Matrices

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English Abstract: Focused ion beam (FIB) sectioning has revolutionized preparation of meteorite samples for characterization by analytical transmission electron microscopy (TEM) and other techniques. Although FIB is not “non-destructive” in the purest sense, each extracted section amounts to no more than nanograms (~500 μm^3) removed intact from locations precisely controlled by SEM imaging and analysis. Physical alteration of surrounding material by ion damage, fracture or sputter contamination effects is localized to within a few micrometers around the lift-out point. This leaves adjacent material intact for coordinate geochemical analysis by SIMS, microdrill extraction/TIMS and other techniques. After lift out, FIB sections can be quantitatively analyzed by electron microprobe prior to final thinning, synchrotron x-ray techniques, and by the full range of state-of-the-art analytical field-emission scanning transmission electron microscope (FE-STEM) techniques once thinning is complete. Multiple meteorite studies supported by FIB/FE-STEM are currently underway at NASA-JSC, including coordinated analysis of refractory phase assemblages in CAIs and fine-grained matrices in carbonaceous chondrites. FIB sectioning of CAIs has uncovered epitaxial and other overgrowth relations between corundum-hibonite-spinel consistent with hibonite preceding corundum and/or spinel in non-equilibrium condensation sequences at combinations of higher gas pressures, dust-gas enrichments or significant nebular transport. For all of these cases, the ability of FIB to allow for coordination with spatially-associated isotopic data by SIMS provides immense value for constraining the formation scenarios of the particular CAI assemblage. For carbonaceous chondrites matrix material, FIB has allowed us to obtain intact continuous sections of the immediate outer surface of Murchison (CM2) after it has been experimentally ion processed to simulate solar wind space weathering. The surface amorphization and loss of OH produced by the irradiation provides important clues regarding space weathering on primitive asteroids such as the OSIRIS-Rex target 101955 Bennu.

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