

STXM IMAGING OF ORGANIC COATINGS ON GRAINS IN PRIMITIVE INTERPLANETARY DUST: IMPLICATIONS FOR FORMATION OF PRE-BIOTIC ORGANIC MATTER AND GRAIN STICKING IN THE EARLY SOLAR SYSTEM

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Chondritic, porous interplanetary dust particles (CP IDPs) are the most primitive samples of extraterrestrial material available for laboratory analysis [1]. These CP IDPs are unequilibrated aggregates of mostly submicron, anhydrous grains of a diverse variety, including olivine, pyroxene, glass, and sulfide. They contain organic matter that was not produced by parent body aqueous processing [2], some carrying H and N isotopic anomalies consistent with molecular cloud or outer Solar System material [3]. Scanning Transmission X-Ray Microscope (STXM) imaging at the C K-edge shows the individual grains in ~10 μm CP IDPs are coated by a layer of carbonaceous material ~100 nm thick. This structure implies a three-step formation sequence for the dust from the Solar Nebula. First, individual grains condensed from the cooling nebular gas. Then complex, refractory organic molecules covered the surfaces of the grains either by deposition, formation in-situ, or a combination of both processes. Finally, the grains collided and stuck together forming the first dust-size material in the Solar System, these CP IDPs.

Ultramicrotome sections, ~70 to 100 nm thick were cut from several CP IDPs that were embedded in elemental S, to avoid exposure to C-based embedding media, and X-ray Absorption Near Edge Structure (XANES) spectra were derived from image stacks obtained using the STXM on Beamline X1A of the National Synchrotron Light Source. "Cluster analysis" was used to compare the C-XANES spectra from each of the pixels in an image stack and identify groups exhibiting similar spectra. When applied to a CP IDP, cluster analysis identifies most of the carbonaceous grain coatings in a particle as material having similar C-XANES spectra.

Two processes are commonly suggested in the literature for production of organic grain coatings. The similarity in thickness and C-XANES spectra of the coatings on different minerals in the same IDP indicates the first, mineral specific catalysis, was not the process that produced these organic rims. Our results are consistent with this primitive organic matter being produced by the alternative process of condensation of C-bearing ices onto the grain surfaces and production of refractory organic matter by UV or other ionizing radiation bombardment of the ices [4].

The processes by which primitive grains aggregate to form the first dust of our Solar System are not well understood. Collision experiments indicate that bare rocky grains bounce apart at collision speeds less than 30 to 50 m/s and shatter each other at larger speeds [5]. However, collision experiments indicate grains coated with organic matter stick quite easily, even at collision speeds up to 5 m/s – an order of magnitude higher than the speed at which silicate- or ice-based grains accrete [6]. Thus the organic grain coatings we have identified probably played a critical role in dust aggregation in the early Solar System.

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