

SUB-MICROMETER SCALE MINOR ELEMENT MAPPING IN INTERPLANETARY DUST PARTICLES: A TEST FOR STRATOSPHERIC CONTAMINATION. G. J. Flynn¹, L. P. Keller², and S. R. Sutton², ¹Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh, NY 12901 (george.flynn@plattsburgh.edu), ²NASA Johnson Space Center, NASA Route 1, Houston, TX, 77058, ³Dept of Geophysical Sciences and CARS, University of Chicago, Chicago IL 60637.

Introduction: Combined X-ray microprobe (XRM), energy dispersive x-ray fluorescence using a Transmission Electron Microscope (TEM), and electron microprobe measurements have determined that the average bulk chemical composition of the interplanetary dust particles (IDPs) collected from the Earth's stratosphere is enriched relative to the CI meteorite composition by a factor of 2 to 4 for carbon and for the moderately volatile elements Na, K, P, Mn, Cu, Zn, Ga, Ge, and Se, and enriched to ~30 times CI for Br [1]. However, Jessberger et al. [2], who have reported similar bulk enrichments using Proton Induced X-ray Emission (PIXE), attribute the enrichments to contamination by meteor-derived atmospheric aerosols during the several weeks these IDPs reside in the Earth's atmosphere prior to collection.

Using scanning Auger spectroscopy, a very sensitive surface analysis technique, Mackinnon and Mogk [3] have observed S contamination on the surface of IDPs, presumably due to the accretion of sulfate aerosols during stratospheric residence. But the S-rich layer they detected was so thin (~100 angstroms thick) that the total amount of S on the surface was too small to significantly perturb the bulk S-content of a chondritic IDP [4]. Stephan et al. [5] provide support for the contamination hypothesis by reporting the enrichment of Br on the edges of the IDPs using Time-of-Flight Secondary-Ion Mass-Spectrometry (TOF-SIMS), but TOF-SIMS is notorious for producing false edge-effects, particularly on irregularly-shaped samples like IDPs.

Sutton et al. [6] mapped the spatial distribution of Fe, Ni, Zn, Br, and Sr, at the ~2 μm scale, in four IDPs using element-specific x-ray fluorescence (XRF) computed microtomography. They found the moderately volatile elements Zn and Br, although spatially inhomogeneous, were not concentrated on the surface of any of the IDPs they examined, suggesting that the Zn and the Br enrichments in the IDPs are not due to contamination during stratospheric residence.

Method and Samples: We have mapped the spatial distributions of several of the moderately-volatile elements using a new XRM on Beamline 2-ID-D at the Advanced Photon Source (Argonne National Laboratory). This XRM has ~200 nm spatial resolution for elements up to Zn, allowing us to measure trace element concentrations at the size scale of the individual mineral grains and the GEMS in the IDPs. The spatial resolution of this XRM for element analysis is com-

parable to that of the nano-SIMS for isotopic analysis, which should allow us to perform element abundance determinations on regions identified as isotopically anomalous using a nano-SIMS.

We tested the idea that the volatile enrichment reported in the IDPs results from contamination by searching for the volatile-rich contamination rims that would be required to produce the high concentrations of the moderately volatile elements previously measured in IDPs.

Ultramicrotome thin-sections, ~70 to 120 nm thick, were prepared from three IDPs – two of them anhydrous, L2009F3 and L2011*B2, and one hydrated, L2008U13. L2011*B2 is a fragment of a “cluster IDP,” a large particle so weak that it broke into tens or hundreds of fragments upon collection, so the surface of this fragment may not have been on the exterior of the particle as exposed in the stratosphere. However, the other two IDPs, L2009F3 and L2008U13, were collected as single particles and their exterior surfaces are likely to be the surfaces that were exposed during stratospheric residence. Element maps were obtained by plotting the signal intensity at each pixel for each element region-of-interest in the XRF spectrum, as shown in Figure 1 for L2009F3, a rather compact IDP having few visible pores that could allow contamination to penetrate to the interior of the particle.

Results: In order to enrich the moderately volatile elements by a factor of 2 to 4 over CI, the edge of each IDP would have to contain a comparable amount of each of the moderately volatile elements to that in the whole interior of the section, an enrichment that would easily be seen in these element maps. To the contrary, each of the moderately-volatile elements detected in these three IDPs is concentrated in one or a few isolated grains in the interior of the IDP. For example, in L2008U13, Zn is enriched in one spot, colocated with S, presumably a Zn-sulfide. The single high-K spot in L2008U13 is also enriched in S relative to the particle average. One high-Mn spot was also detected in L2008U13. This spot is also enriched in Mg, but has much lower S and Ni than the particle average, possibly indicating it is a carbonate.

The surface enrichment of S detected by Mackinnon and Mogk [3] is not seen in our S-map of L2009F3 (or either of the other two IDPs we mapped). But we did not expect to detect this S layer because it was very thin in Mackinnon and Mogk's analysis [3], and was

below our detection limit when spread over the ~200 nm analysis spot of these measurements.

Conclusions: These new analyses confirm the Zn results previously reported by Sutton et al. [6] and significantly extend those measurements since the L2009F3 and L2008U13 maps show no evidence for surface enrichments of the moderately volatile elements S, Mn or Zn and the map of the high-K fragment, L2011*B2, shows K collocated with the silicate, with no evidence for a K-rich rim. These measurements indicate that the bulk enrichments in the moderately volatile elements reported in IDPs by Flynn et al. [1] are not contamination, as has been suggested by Jessberger et al. [2], but, rather, they are likely to be indigenous.

Each of the elements we mapped is concentrated in only a few hot-spots. The identification of the host mineral(s) of each of these elements in the primitive, anhydrous IDPs by TEM analysis should provide constraints on the conditions of the Solar Nebula at the time of grain formation, while the identification of the host mineral(s) of each of these elements in the hydrated IDPs should provide constraints on the compo-

sition, temperature, pH, etc. of the fluid that produced the aqueous alteration of the hydrated IDPs.

Acknowledgements: This work was supported by a NASA Cosmochemistry Grant (NAG-5-12976) to G.J.F. Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Office of Basic Energy Sciences (Contract No. W-31-10). We thank B. Lai and S. Vogt for valuable technical assistance.

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Figure 1: Element distribution maps in L2009F3 (highest element concentrations are red). The blue region in the Fe map shows the particle boundary. The maps [S (top left), Ca (top middle), Cr (top right), Fe (bottom left), Ni (bottom middle), and Zn (bottom right)] show no evidence of element concentrations along the edge, suggesting that contamination does not contribute significantly to any of the elements mapped.

