ISOTOPE RATIO IMAGING OF INTERPLANETARY DUST PARTICLES; R. H. Fleming, G. P. Meeker(1), F. Radicati di Brozolo, Charles Evans & Associates, Redwood City, CA 95063; D. F. Blake, NASA/Ames Research Center, Moffett Field, CA 94035; and L. D. White, USGS, Menlo Park, CA 94025.

The elemental, isotopic, textural, and molecular analysis of interplanetary dust particles (IDP) presents a unique opportunity for the study of materials preserved in a relatively pristine condition from the early solar system and possibly the interstellar medium.(2) A useful model for the condensation of hydrogen containing molecules into solid phases assumes that pre-existing grains of mineral matter accurate hydrogen (and carbon) containing substances as they pass through the cold molecular clouds. These clouds exist at very low temperatures (< ~100 K) at which the deuterium-to-hydrogen ratio can be substantially increased by fractionation due to ion-molecule reactions.(3) The detection of high deuterium enrichments in IDP samples serves to identify and locate possible pre-solar material. Variability of isotope ratios within a single IDP particle could arise from the heterogeneity of grains accreted in the IDP, or from partial H/D exchange with an external source of hydrogen such as the comet ice. To examine such questions, we developed the technique of secondary ion mass spectrometry (SIMS) isotope ratio imaging, which we report along with some initial results on IDP.

The CAMECA IMS-4f ion microprobe can produce ion images by rastering the primary ion beam and recording ion intensities as a function of primary ion position. Charles Evans & Associates imaging software can record and store these images at a user defined sequence of different m/z ratios and repeat the sequence indefinitely. This is termed an image depth profile analysis. The currently available Cs^+ primary ion source is capable of producing ~0.5 μm lateral image resolution. This instrumental configuration is well suited for D/H isotope ratio image measurements. New software converts deuterium and hydrogen ion images into isotope ratio images.

The main difficulty in the measurement of D/H isotope ratio images is that the already sparse deuterium signal is spread among many pixels. If one assumes an H^- signal of 5×10^5 ions/s, then natural abundance D^- occurs at ~80 ions/s and deuterium image acquisition requires about 23 hours for 100 D^- ions in each of 65,000 pixels. Since lateral image resolution depends only on the primary beam diameter, the smallest resolvable features in high magnification images are often represented by too many pixels. This over sampling reduces the number of counted ions in each pixel and leads to ratio images with low signal-to-noise values. Convolution of both the numerator and denominator images before ratioing brings the apparent image resolution into agreement with the actual instrument resolution.

The problem of secondary ion intensity drift during image acquisition is partially alleviated by alternately acquiring deuterium and hydrogen images in an image depth profile mode. The new software provides for pixel-by-pixel summing of the numerator and denominator images and correction for individual pixel detector dead time losses before calculating the D/H ratios. Ion images furnish highly useful information from the areas surrounding the particle. If the D/H ratio of the particle mounting medium (e. g., epoxy resin) is known, then this mounting medium provides a reference material to measure any mass bias effects in the isotope ratio measurement. Imaging provides more accurate mass bias corrections because both the IDP particle and the reference sample are measured in the same experiment. Isotope enrichment and depletion images relative to a standard (usually Standard Mean Ocean Water) are calculated from the deuterium and hydrogen images.

Ion microprobe SIMS imaging and the above software have been used to produce isotope ratio images of IDP particles and thin sections as shown, for example, in Figure 1. This thin section was microtomed from an IDP particle (IDP # Ames-Dec86-11) that had already been extensively studied.(4) Eight 600 s deuterium images and seven 10 s hydrogen images were acquired in DHDHDHDHDHDHDHD order using the imaging depth profile procedure. The images were acquired in the scanning ion microprobe mode with a ~2 μm diameter 25 pA primary Cs^+ beam rastered over 50 μm. A convolution size of 9 x 9 was used which raises the pixel intensity by an average factor of 81. The particle appears to be extraterrestrial since the deuterium enrichment is higher than would be reasonable for a terrestrial or analytical artifact. The deuterium enrichment is also heterogeneously distributed.

REFERENCES AND ACKNOWLEDGEMENT: (1) Present address; USGS, Federal Center, Denver, CO 80225; (2) J. A. Wood and S. Chang, Eds., The Cosmic History of the Biogenic Elements and Compounds, NASA SP-476, 80 (1985); (3) J. Geiss and H. R. Reeves, Astron. Astrophys. J., **93**, 189 (1981), and D. Smith, N. G. Adams, and E. Alge, Astrophys. J. **263**, 123 (1982); (4) D. F. Blake, A. J. Mardinly, C. J. Echer, and T. E. Bunch, Proceed. Lunar Planet. Sci., XVIII, 615 (1988); Supported by NASA SBIR Phase I contract NAS2-12818.

Figure 1. Deuterium (upper left) and hydrogen (lower left) images of interplanetary dust particle. Deuterium enrichment image (upper right) and deuterium enrichment along the line (lower right).