Three-dimensional iron mapping of cosmic dust samples using subtraction microtomography.

Akira Tsuchiyama[1], Kentaro Nakamura[1], Kentaro Uesugi[2], Tsukasa Nakano[3], Takaaki Noguchi[4], Keiko Nakamura[5], Tomoki Nakamura[6], and Yoshio Suzuki[2]

1) Department of Earth and Space Science, Osaka University, 1-1 Machikaneyama-cho, Toyonaka 560-0043, JAPAN, akira@ess.sci.osaka-u.ac.jp. 2) JASRI/SPring-8, Mikazuki, 679-5198 JAPAN. 3) AIST/GSJ, Tshukuba, 305-8567 JAPAN. 4) Depart. Material and Biological Sci., Ibaraki University, Mito 310-8512, JAPAN. 5) Graduate School of Science, Kyushu University, Fukuoka, 812-8151, JAPAN. 6) NASA/JSC, Houston, TX, 77058, USA.

We have performed 3-D Fe mapping of cosmic dust nondestructively using a SR projection microtomography system at BL47XU of SPring-8. Extraterrestrial materials of < 1 mm are called cosmic dust in contrast to meteorites (> 1 mm). As they have a wider variety of origin than primitive meteorites, specific information that cannot be obtained from meteorites alone could be extracted from cosmic dust.

Distribution of a specific element can be obtained by X-ray CT using two energies just above and below the absorption edge of the element. This subtraction method has been applied to mapping of heavy elements. Lately, high-resolution quantitative 3-D Cs mapping was obtained for a Cs-doped molten granite sample (this volume and [1]). Fe and Ni are naturally abundant and heavy elements. However, their edge energies are so low that the method has not been applied to natural samples.

In the present study, using cosmic dust of <100 micron combined with microtomography of the resolution of <1 micron gave Fe mapping of the natural samples successfully. One standard sample (olivine) with known Fe content and density and three cosmic dust samples were imaged at X-ray energies just above and below the Fe K-edge (7.124 and 7.098 keV, respectively) with the pixel size of 0.2 micron. To minimize the effect of harmonics a monochrometer was detuned and a helium path for reducing the decay of ~7keV X-ray beams by air was used. Comparison of linear attenuation coefficients (LACs) of some standard materials with their theoretical LACs shows that the effect of harmonics was negligibly small. Two sets of CT images at the different X-ray energies were slightly shifted each other three-dimensionally even by a small shift of X-ray path. The shift was adjusted using an appropriate algorithm before obtaining subtraction images. 3-D Fe concentration map was obtained for the olivine sample directly from the subtraction images. The average Fe concentration in the Fe map was almost the same as the real concentration. 3-D Fe concentration maps of the cosmic dust samples were obtained by assuming a density – Fe content relation for common minerals in cosmic dust. The Fe contents of Fe-rich regions in the Fe maps are generally smaller than those analyzed by an electron probe micro analyzer. The discrepancy is probably due to the effect of Fe fluorescent X-ray generated above the Fe edge energy.

Reference: [1] Ikeda et al. (2004) Am. Mineral., 89, 1304-1313.