# SR-based analytical micro-nanotomography and its appication to extraterrestrial materials

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X-ray computed tomography (CT) is a nondestructive method for determining the 3D internal structure of an object by using information such as absorption and phase difference of x-rays. SR x-rays produce CT images with high S/N ratios and high spatial resolution. Nanometer-scale resolution (>~30 nm) has been obtained by using imaging optical system with a FZP at SPring-8 (e.g., [1]).

Quantitative information about the size (e.g., length and volume) are obtained from CT images. By using monochromatized x-rays, quantitative information about absorption and phase contrasts can be obtained too. However, it is sometimes diffuicult to discriminate between minerals from its linear attenuation coefficient (LAC) alone in absorption tomography. Elemental images were obtained from a set of absorption images measured below and above the absorption edge energy of the element [2]. However, the concentration cannot be obtained without the density.

We have developped a new technique called “analytical dual-energy microtomography” that uses the LACs of minerals below and above the absorption edge energy of an abundant element (e.g., Fe) to nondestructively obtain 3D images of mineral distribution [3] and successfully applied to particles collected by the Hayabusa spacecraft [1]. By combining with FIB micro-sampling from a thin section, we can obtian 3D images for regions of interest [4].

In absorptin tomography, it is difficult to discriminate between void, water and organic materials because their LACs are similar. In contrast, we can discriminate between them in phase tomography, which have information of the refractive index by x-ray. Phase and absorption contrast images can be simultaneously obtained in 3D by using scanning-imaging x-ray microscopy (SIXM) [5]. We applied this technique combined with FIB micro-sampling to carbonaceous chondrites to search for primitive liquid water.

**REFERRENCES**: [1] Tsuchiyama et al. 2011 *Science* 333, 1125. [2] Thompson et al. 1984 *Nucl. Instr. Meth. Phys. Res.* 222, 319. [3] Tsuchiyama et al. 2013 *GCA*, 116: 5. [4] Tsuchiyama et al. 2014 *MAPS*, 49: A404. [5] Takeuchi et al. 2013 *J. Synch. Rad.*, 20: 793.