1. INTEGRATED SYNCHROTRON RADIATION COMPUTED TOMOGRAPHY SYSTEM FOR THE ANALYSIS OF EXTRATERRESTRIAL MATERIALS

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Synchrotron radiation (SR) computed tomography (CT) is one of the important tools for the analysis of extraterrestrial materials [e.g. 1], especially returned samples by spacecraft missions [2,3,4], because of its non-destructive feature. X-ray with high photon flux density, high energy and high coherent enables us to investigate mm-sized sample with micron to sub-micron of spatial resolution, three dimensionally. However, there are several problems in the CT observation of those extraterrestrial materials. Higher spatial resolution makes narrower field of view (FOV). Thus, if we intend to observe whole structure of large sample by X-ray CT, we should apply CT system with lower spatial resolution. In other words, we should break the sample into small pieces if we want to observe the sample with higher spatial resolution. In addition of those problems, we can not determine the materials inside the unknown samples only by the CT. We can observe the internal texture, which shows difference of X-ray linear absorption coefficient (LAC) [4,5,6] in the material by CT. However, the value of LAC for mineral phases inside the extraterrestrial material significantly overlaps each other. Thus it is difficult to distinguish the mineral phases uniquely only by the LAC and texture.

Recently, those problems are gradually resolved by multi-mode and multi-scale tomography technique. In BL20XU/SPring-8, we constructed an integrated CT system, which consists of three X-ray beam monitors those having different spatial resolution and FOV, and several optical elements, such as Fresnel zone plate (FZP). By changing X-ray beam monitors and optical elements with repeatability error much less than the spatial resolution of the system, we can measure a sample with multiple SR-CT methods. Currently, normal absorption contrast CT with two different resolution, Wide FOV and Low spatial resolution mode (WL mode) and Narrow FOV and High spatial resolution mode (NH mode), scanning x-ray diffraction (SXRD), X-ray diffraction CT (XRD-CT) and differential phase contrast CT (DP-CT) are available in the integrated CT system. X-ray energy used in this system is 30 keV, which is enough to penetrate extraterrestrial samples around 5 mm in diameter [5]. We can choose the set of pixel size of WL mode and NH mode. For the setup of larger samples, pixel size and FOV are 3 μm and 6 mm for WL mode and 0.25 μm and 0.5 mm for NH mode. For setup of smaller samples, pixel size and FOV become 0.5 μm and 1 mm for WL mode and 50 nm and 60 μm for NH mode. In SXRD mode, X-ray was focused into 1 μm spot. Samples are scanned by the focused X-ray beam, and diffraction image was obtained for each scanning point by the X-ray beam monitor with pixel size of 20 μm and FOV of 40 mm. Then mineral composition of each position can be obtained. If we scan a sample horizontally by the focused X-ray with rotating the sample using the SXRD setup, we can obtain the texture of the mineral phases in a horizontal plane by XRD-CT. DP-CT is under the development, but we can obtain CT images with high sensitivity for the materials consist of light elements, such as carbon, with pixel size around 0.1 μm.

We can obtain information of samples with the system from several aspects without breaking it. The system can provide an important start point for the analysis of extraterrestrial samples, expecially samples returned by spacecraft missions, such as Hayabusa2, OSIRIS-REx and MMX.

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