BL20XU
Medical and Imaging II

1. Introduction

BL20XU, which is the only medium-length (250 m) beamline with an undulator source in SPring-8, is designed for application to various imaging techniques. A liquid-nitrogen-cooled Si double-crystal monochromator (DCM) is used to choose the X-ray energy [7.67–37.7 keV with Si(111) reflection and 12.4–61.5 keV with Si(220) reflection]. In order to transport a clean and coherent X-ray beam, no X-ray optical devices except the DCM and X-ray windows are installed. There are two experimental hutches; experimental hutch 1 (EH1) is located 80 m from the source, and experimental hutch 2 (EH2) is located 245 m from the source. Various types of X-ray projection imaging, such as X-ray microcomputed tomography (μ-CT), X-ray high-speed imaging, and coherent X-ray imaging, are available. By using both EH1 and EH2, two types of experiments unique to BL20XU, both of which require a long sample-to-camera distance (165 m) are available; one experiment is that on ultrasmall-angle X-ray scattering (USAXS), and the other is on high-energy X-ray nano-tomography (nano-CT). Multiscale CT combining μ-CT and nano-CT, and an integrated CT (Fig. 1) consisting of multiscale-CT and X-ray diffraction CT (XRD-CT) are now newly developed. As part of activities in this beamline, improvements of the software of XRD-CT have been carried out.

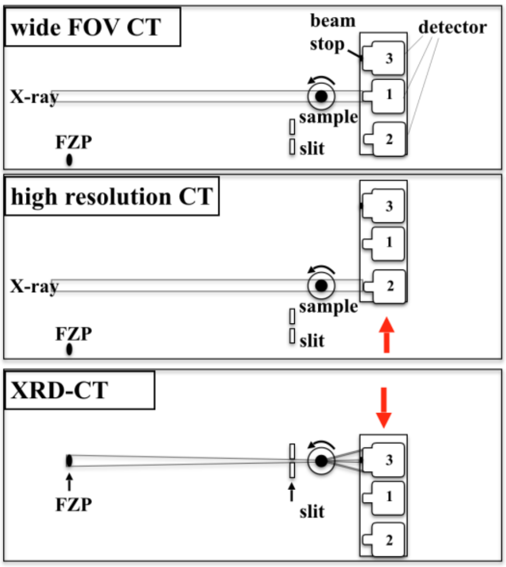

Fig. 1.Schematic diagram of integrated CT at BL20XU.

2. Software update of XRD-CT in integrated CT system

XRD-CT, which incorporates both microbeam-XRD and CT measurement methods, enables us to observe internal structures of a material along with crystallographic information [1, 2]. The system is composed of three detectors, and it has pixel sizes of 3 μm (FOV = 6 mm) and 0.25 μm (FOV = 0.5 mm) for multiscale CT, and a pixel size of 20 μm (FOV = 40 mm) for XRD observation. A Fresnel zone plate (FZP) can be installed for XRD measurement to produce a 30 keV X-ray focused probe with a few μm spot size. Such a high-energy X-ray probe can penetrate through rocky materials with a diameter up to ~ 5 mm.

The system is applied to the observation of rare and precious materials such as extraterrestrial materials, which include meteorites and samples brought from spacecraft, and historical samples. In addition to static samples, recently, the system has been applied to the observation of dynamic samples, such as melting and/or resolidifying materials, and the development process of fatigue failures. XRD measurement is important not only for the determination of unknown materials but also for the determination of the changes in crystal structure during such dynamic phenomena.

Two-dimensional maps of mineral phases can be obtained by XRD-CT. Figure 2 shows XRD-CT images of Murchison meteorite. In previous analyses, XRD-CT images were reconstructed using the peak intensities of diffraction data from the mineral phases. In this case, diffraction only occurs when the mineral phase satisfies Bragg's condition during a half rotation of a CT image. Then, a discrete signal of diffraction data was used for CT image reconstruction, although such signal causes large amounts of noises in the image [Fig. 2(b)]. If mineral grains are much smaller than the focused X-ray spot, and multiple grains are illuminated within the X-ray beam, the diffraction of the mineral grains appears as a ring, and the XRD-CT image shows less noise.

In order to solve the problems encountered, two modifications were made on the XRD-CT reconstruction software. First, multiple peaks were used for XRD-CT reconstruction. Second, the grain boundary method, which uses changes in diffraction between grain boundaries during translation scanning, was applied. In the grain boundary method, the change of the diffraction pattern during translation scanning was calculated. Then, the absolute value of the difference from the previous step of translation scanning was used for CT reconstruction. As seen in Fig. 2(c), grain boundaries are enhanced and visualized by this method [3]. Figure 2(d) shows the result of the combination of two modifications. Compared with the result obtained using the conventional reconstruction [Fig. 2(b)], olivine grains in Murchison meteorites are greatly enhanced in the XRD-CT image. The combination of XRD-CT images of olivine and pyroxene peaks gives the complete image of inclusions [Fig. 2(e)].

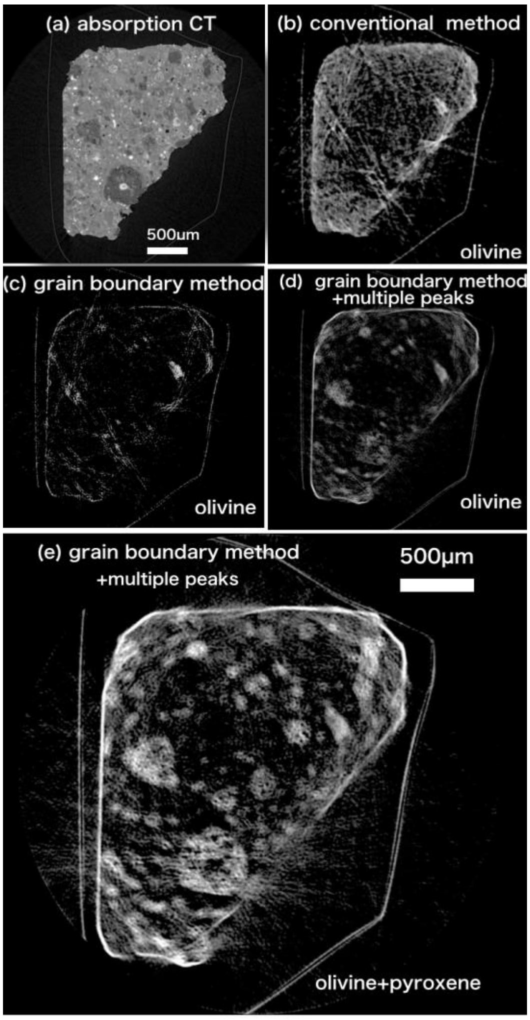

Fig. 2. XRD-CT images of Murchison meteorite. (a) Absorption CT image, (b) XRD-CT image of olivine grain reconstructed by the conventional method, which uses single peak intensity, (c) the same image but reconstructed by the grain boundary method using a single peak, (d) the same image but reconstructed by the grain boundary method using multiple peaks. (e) XRD-CT image reconstructed by the grain boundary method using multiple peaks of olivine and pyroxene.

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