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X-ray computed tomography imaging of structure materials using synchrotron radiation

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1 Introduction

Silicon carbide fiber-reinforced silicon carbide matrix (SiC/SiC) composite is a promising material for high-temperature applications such as aerospace propulsion systems owing to its excellent thermal and chemical stability [1]. Since non-destructive characterization of the SiC/SiC is important to the characteristic elucidation and improvement, evaluation technique has been widely studied. As one of the methods, the 3D geometrical characterization of the SiC/SiC by synchrotron radiation x-ray computed tomography (CT) was performed in order to verify the possibilities of this technique.

In this study, both absorption contrast CT and phase contrast CT were applied to SiC/SiC composite materials to obtain the information about the shape, dimensions and position of large voids, cracks or pores.

2 Experiment

The experiments were performed at the vertical wiggler beamline BL-14B and BL-14C [2]. The x-ray energy was adjusted to 20.6 keV using double-crystal monochromators. The incident beam was collimated and expanded in the horizontal direction by an asymmetrically cut Si(220) crystal (α = 8 deg.) to produce an x-ray beam with uniform intensity. The x-rays transmitted through a sample were expanded by a Si(220) asymmetric analyzer crystal (α = 6 deg., magnification factor is about 5) in the horizontal plane, then the x-rays diffracted by the analyzer were recorded on an x-ray charge-coupled device (CCD) camera (Photonic Science, VHR). The x-ray CCD camera consisted of a GdO_2S:Tb scintillator, a glass fiber plate (taper =1:1) and a CCD sensor. The effective pixel size was 7.4 μm (H) × 7.4 μm (V), and the number of pixels were 4872 (H) × 3248 (V). A series of radiographic images taken with rotating the sample around the vertical axis are reconstructed via filtered back-projection (FBP) method [3].

In the case of the phase contrast CT, three-image diffraction enhanced x-ray imaging (DEI) method [4] was employed to obtain the absorption, refraction and ultra-small-angle scattering images.

The SiC/SiC in the shape of 2.5 × 2.8 × 9.6 mm^3 was prepared for the sample.

3 Results and Discussion

Volume rendering of the absorption contrast CT images of the SiC/SiC sample is shown in Fig. 1(a). The woven fiber bundle structure and fiber direction are visible. Figure 1(b) shows the porous network that was extracted from fig. 1(a). Although most of the pores drawn in the figure are intra-ply pores, some inter-ply pores are seen. The average porosity obtained from these data was 18.7±0.1%, in good agreement with the calculated porosity 20.6%.

Figure 2 shows two-dimensional CT images for the directions of perpendicular to the y-axis in Fig. 1. Figure 2(a) is an absorption contrast CT, where the contrast between the sample constituents is due to the intrinsic differences in linear attenuation coefficients. Figure 2(b) reconstructed from the DEI-CT data shows the refraction angle image that occurs when x-rays are refracted from their initial path while traversing the sample. For the materials consisting of light elements, the DEI generally provides improved contrast compared to the absorption radiography. In this case, the detailed structure such as the disorder of the fiber bundle, which is invisible in Fig. 2(a), is seen in Fig. 2(b). However, it is hard to say that the effect of the phase contrast method is extremely remarkable as a whole. And complementary application of absorption contrast CT and DEI-CT is expected to

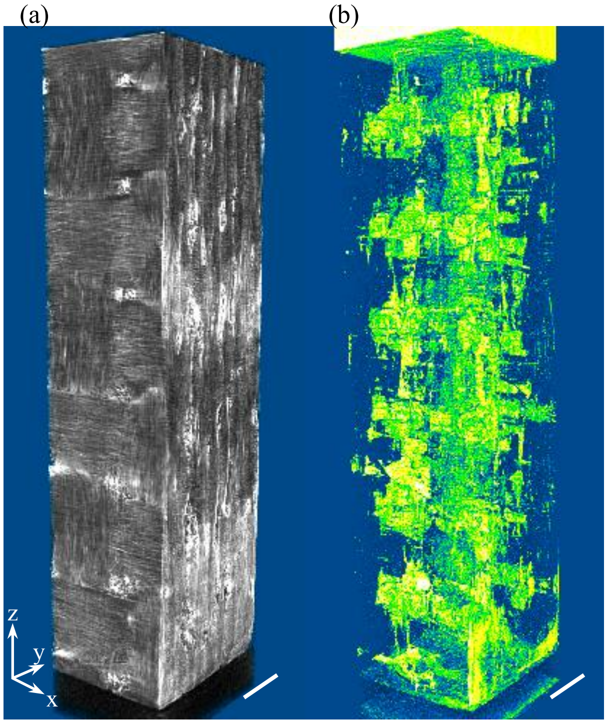

Fig. 1: 3D images of the SiC/SiC obtained by absorption contrast CT
(a) 3D volume rendering image and (b) porous network. Measured images expanded horizontally were reduced to the original ratio by image processing. Scale bars indicate 1mm.

provide detailed information on microstructures, large voids, cracks or pores of SiC/SiC composite materials.

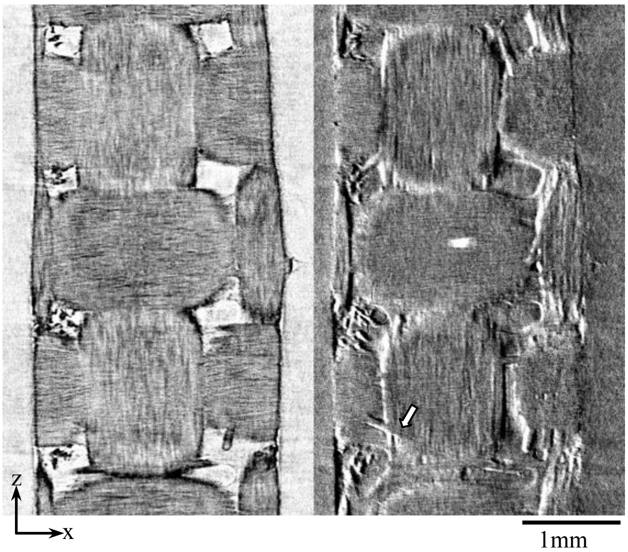

Fig. 2: 2D reconstructed tomographic slices of (a) absorption contrast CT and (b) refraction angle image obtained by DEI-CT of the SiC/SiC. Arrow indicates the disordered fiber bundle.

4 Conclusion

The absorption contrast CT and the DEI-CT using synchrotron radiation provide 3-D images of the internal structure of SiC/SiC composite in high quality. The results showed the potential for the quantitative analysis of porosity and density using these techniques. Further optimization of measuring conditions will be carried out for the next step.

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