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Structure Investigation of ZrO_2 Fiber Insulation Tile by Using Synchrotron X-ray In-line Phase Contrast Microtomography

Shengkun Yao[1], Benxue Liu[2] and Yangjian Cai[1]

[1]Shandong Normal University, Ji'nan, Shandong, China (People's Republic), [2]Qilu University of Technology (Shandong Academy of Sciences), Ji'nan, Shandong, China (People's Republic)

*Corresponding author: yaoshk@sdnu.edu.cn, liubenxue@sdas.org.

With the development of synchrotron radiation light sources worldwide, X-ray microscopies show broader applications in material science, biology and industrial area [1, 2]. The microscopies can perform structural analysis at high resolution without destroying the tested samples owe to the strong penetration power and short wavelength of X-rays. Recently, to improve the image contrast, various phase-contrast imaging techniques have been developed, including propagation-based imaging (i.e. in-line phase-contrast imaging), X-ray interferometry, grating-based imaging, and analyzer-based imaging [1]. Among the phase-contrast imaging methods, in-line phase-contrast X-ray imaging is suitable for biological applications due to its simplicity. A beam with sufficient spatial coherence and appropriate sample-to-detector distance can attain phase contrast information without any additional optical components. The acquired projections can be reconstructed with and without phase retrieval at a single distance to emphasize characteristic structures [3, 4].

In this study, we performed the structural investigation of a ZrO_2 fiber insulation tile, which is widely applied as thermal protections for furnace, nuclear reactor, spacecraft, etc., by using synchrotron X-ray in-line phase contrast microtomography. The non-destructive determination of the integral microstructure is significant for valuing the mechanical and insulating performances of the insulation tile. The insulation tile with a size of 2×3×5 mm was fabricated according to ref [5]. In-line phase contrast X-ray images were acquired with the beamline BL13W1 at the Shanghai Synchrotron Radiation Facility (SSRF). A collimated 35 keV X-ray beam was monochromatized by a double Si (311) crystal system. When the X-ray beam traverses the sample, the exiting beam carries both absorption and phase shift information. After propagating a sufficient distance (100 cm), the phase shifts were transformed into measurable intensity variations by Fresnel diffraction. A CCD detector with 2048×2048 pixels (pixel size of 6.5×6.5 µm) was used to transform the beam into an image. The specimen was fixed on a rotary stage strictly calibrated to parallel the CCD camera, and rotated 180° during data acquisition. The detector collected 1200 projection images from 0° to 180° with a 0.15° rotation interval and the exposure time for each projection is 6 ms. Two flat images without sample in beam path were collected every 200 projections used to calibrate the background. Five dark images were recorded to eliminate the CCD dark noises without X-rays in the beam path. The tomographic reconstruction, including background correction, rotating axis position correction, and filtered back projection (FBP) reconstruction, were carried out by a CT software compiled by the BL13W1 station [6]. Subsequently, the three-dimensional images of the sample were visualized with Amira software.

In summary, we performed the synchrotron X-ray in-line phase contrast microtomography of a ZrO_2 fiber insulation tile. The morphology and internal structures were investigated nondestructively [7].

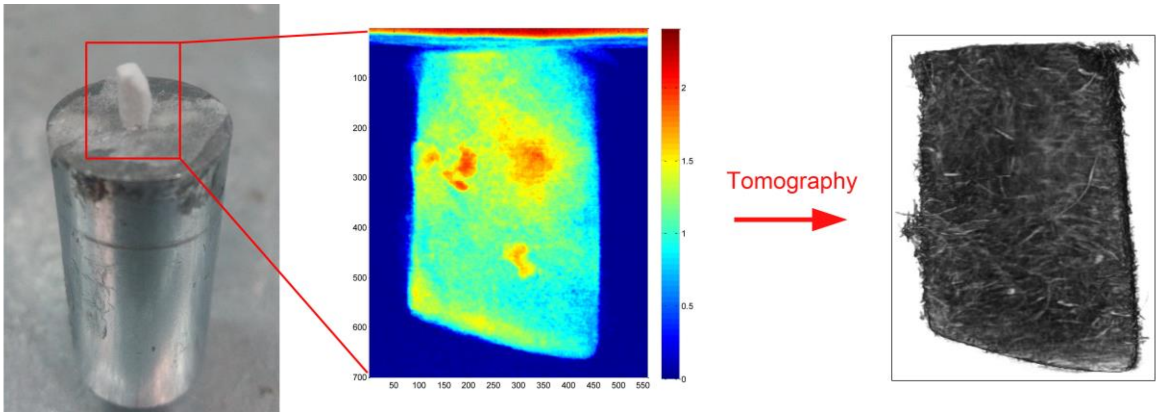

Figure 1. Tomography of a ZrO2 fiber insulation tile.

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