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Defect Structure Investigations in Amorphous SiO_2 Induced on Swift Heavy Ions by SAXS

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1 Introduction

Radiations such as neutron, x-ray, swift heavy ions and etc. interact with materials and cause structural changes. They are, therefore, applied to material processing, modifications and etc. Swift heavy ion (SHI) irradiation provides high energy deposition through electronic stopping to the materials. SHIs in insulating solid materials can leave trails of damage with diameters of several nanometers along the ion path, so called ion tracks. The defect structures in crystalline materials were detected as lattice mismatches by diffraction techniques, especially using transmission electron microscopy (TEM). On the other hand, for amorphous materials, subtle density changes between track and matrix material are required to be observed. Tracks in amorphous SiO_2 are attracting attention due to its applications in a wide range of fields. In this study, we investigated ion track shapes in amorphous SiO_2 induced on SHI irradiation using small angle x-ray scattering (SAXS).

2 Experiment

Silica glass (a-SiO_2) plate (ATOCK Co., Ltd) were irradiated with 100 MeV Kr ions to fluence of 3×10^{11} cm^{-2} at H1 beamline of the Tandem ion accelerator facility in Japan Atomic Energy Agency (JAEA)-Tokai. The irradiation experiment was performed at room temperature in a vacuum. The sample thickness was 100 μm for sufficient X-ray transmittance in SAXS measurements and the penetration depth of injected Xe ions was estimated within 20 μm by SRIM code [1]. For the given fluence range, track overlap was negligible. The SAXS measurements were carried out at BL-6A in KEK-PF, Japan using an X-ray wavelength of 1.5 Å (8.27 keV) and a camera length of 1.0 m. Images were taken in transmission geometry using a two-dimensional pixel-array detector (PILATUS-300K-W, DECTRIS) with an exposure time of 600 s. Unirradiated SiO_2 specimen was also measured as a standard for background removal.

3 Results and Discussion

Figure 1 shows SAXS images of an a-SiO_2 specimen irradiated with 100 MeV Kr ions to a fluence of 3×10^{11} cm^{-2}. Radial symmetrical image was observed at the X-ray beam incident parallel to the direction of SHI irradiation as shown in Fig. 1 (a). On the other hand, streaks are apparent in the images on tilting geometry between the sample surface and the X-ray (Fig. 1(b-d)). The width and curvature of streaks are clearly observed to be narrower and smaller, respectively, with increasing of the tilting angle. These image behaviors dependent on the tilting conditions are due to elongated cylinder-shape scattering substances, which have thin disc-shape in reciprocal space [2]. Previous study of a-SiO_2 irradiated with 89 MeV Au has observed similar SAXS image behavior [3]. Detailed track shapes are currently under analysis assuming a homogenous cylindrical model.

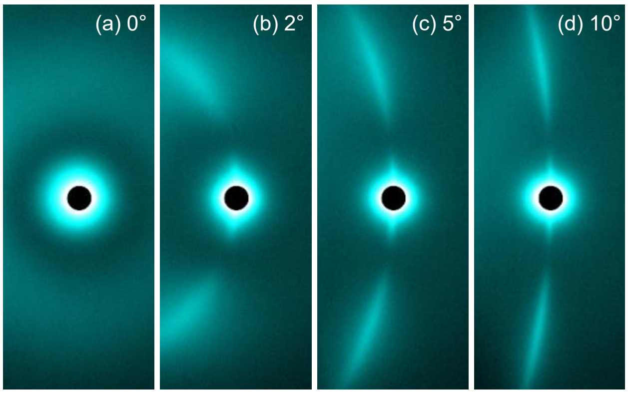

Fig. 1: SAXS images of SiO_2 irradiated with 100 MeV Kr to a fluence of 3×10^{11} ions/cm^2. (a) The sample was set with the X-ray beam incident parallel to the direction of SHI irradiation. (b-d) The sample was tilted to 2°, 5°, 10°, respectively with respect to the X-ray beam. The central spot without intensities in each image is the catcher for the incident X-ray beam.

References

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