

§79. Surface Analysis of Effect of Plasma Irradiation to Nuclear Fusion Materials

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Development of materials suitable for divertor components is an essential issue for realization of fusion reactor. The objective of this study is to provide the basic data for material development by using high heat-flux plasma flow emitted from the large tandem mirror device. In this research, we irradiate the various materials that will become candidates of divertor components with plasma flow with high heat-flux emitted from the end-mirror throat of the GAMMA 10 tandem mirror and investigate the difference between the circumstances of the irradiation in the GAMMA 10 end-cell and those of actual divertor regions in tokamaks from the viewpoint of surface analyses.

Here we used commercially available 4H- and 6H-SiC single crystal plates with a size of 15 x 15 x 0.5 mm. The W disks of 8 mm diameter with 0.5 mm thickness, was cut from single crystal rods prepared by the floating zone melting method. The sample holder made of Mo was attached on a transfer rod, which can be adjusted to locate at 0.3 m from the end of the mirror exit. The irradiation was performed in typical hot-ion-mode plasmas with two different conditions as shown in Table 1.

The surface analysis was performed by using the surface analysis system with high-energy He beam (1.7 MeV) at the Institute of Materials Research, Tohoku University¹⁾. After the plasma exposure, the sample was analyzed by Rutherford backscattering (RBS) in a channeling condition and by the elastic recoil detection (ERD) methods for deposited metal impurities and retained hydrogen atoms in the surface layer of it, respectively.

Figure 1 shows the result of RBS analysis in the two irradiation conditions (Case 1 / Case 2) in the case that the analyzing He beam is injected with the direction of <0001>. In the exposed specimen, as shown in the figure, Cr, Fe and Ni, which are component of the stainless steel, are detected together with a small amount of Mo and W. Noted that the remarkable difference is recognized in irradiation condition.

Concentration depth profiles of displaced Si atoms in SiC single crystals irradiated by two different plasma conditions were shown in Fig. 2, together with the calculated one caused by 350 eV H ion irradiation as a solid curve. Compared with the calculation, the observed damaged layer extended to significantly deeper and broader depth region. On the other hand, the amount of trapped hydrogen in Case2 is higher than that in Case1 by few times, although the difference in fluence between Case 1 and Case 2 is more than one order of magnitude. The discrepancy is probably due to the thicker deposition layer formed under Case 2, where the kinetic energy of the impinging hydrogen

Experiment	Case 1	Case 2
Ion energy (eV)	150	350
Flux ($\text{m}^{-2}\text{s}^{-1}$)	1e21	3e22
Fluence (m^{-2})	1e22	4e23

Table 1 Plasma parameters for irradiation experiments of Case 1 and Case 2.

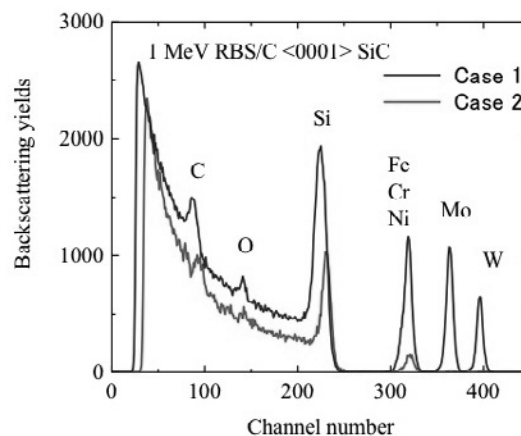


Fig.1 Comparison of RBS spectra between different irradiation conditions on SiC single crystals.

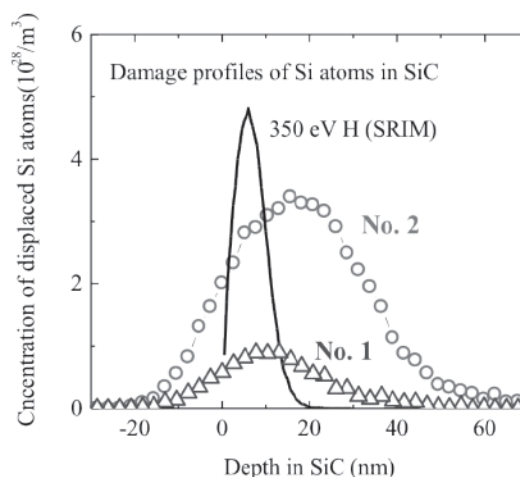


Fig. 2 Depth profiles of displaced Si atoms of SiC single crystals and injected hydrogen atoms.

was lost. While the black colored area was clearly seen in the SiC crystal, no visible changes was found in the W crystal. Comparing to the SiC crystal, the accumulation of the metal impurities and the displacements in the W crystal were estimated to be approximately 1/10 and 1/15 respectively. This was attributed to the higher reflection efficiency and lower energy transfer in collisional events because of the higher atomic number of W. No difference of the recoil hydrogen spectra from the W crystal was observed between before and after irradiation.

1) Nagata, S., et al., J. Alloys and Compounds **446-447** (2007) 558.