§9. Surface Analysis of Nuclear Fusion Materials Irradiated by GAMMA 10 Plasma

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It is a promising approach for studying the plasma-wall interactions in divertor regions in tokamaks to simulate plasma by the liner devices. Divertor simulation experiments have been started in the GAMMA 10 tandem mirror while repeating improvement of the plasma parameters. In the previous experiment, we demonstrated that impinging particles from the plasma and their effects on the materials can be quantitatively examined using SiC crystals inserted in the end-mirror throat of the GAMMA 10. In this report, we describe the accumulation of hydrogen related with the irradiation induced damage, and of the impurity metals, in divertor candidate materials such as SiC and W in different plasma irradiation condition.

The SiC samples were commercially available 4H- and 6H-SiC single crystal plates having 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. 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. The ion beam measurements were carried out using a 1.7 MV tandem accelerator.

Concentration depth profiles of displaced Si atoms in SiC single crystals irradiated by two different plasma conditions were shown in Fig. 1, including the calculated one caused by 350 eV H ion irradiation as a solid curve. The depth resolution of the RBS measurements was estimated to be less than 10 nm under the present experimental condition. Even after taking it into consideration, the observed damaged layer extended to significantly deeper and broader depth region, in comparison to the calculation.

The areal density of the retained hydrogen, the displacements and the deposited metals were shown in Fig. 2. The plasma flux and fluence under condition B was an order of magnitude larger than those under condition A. The hydrogen retention and the displacements, however, were several times as large at most. The discrepancy is probably due to the thicker deposition layer formed under condition B, where the kinetic energy of the impinging hydrogen 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. The retention of hydrogen in the W crystal was below the detection limit of the ERD technique in the present condition, approximately 10^{19} cm^{-2}.

irradiation	A	B
ion energy(eV)	150	350
flux ($m^{-2}s^{-1}$)	1e21	3e22
fluence (m^{-2})	1e22	4e23

Table.1.Plasma parameters for irradiation A and B.

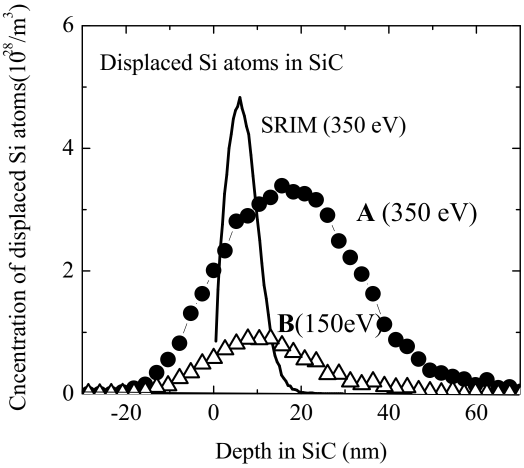

Fig. 1. Concentration depth profiles of Displaced Si atoms of the SiC single crystals irradiated at the end of the mirror exit of GAMMA10

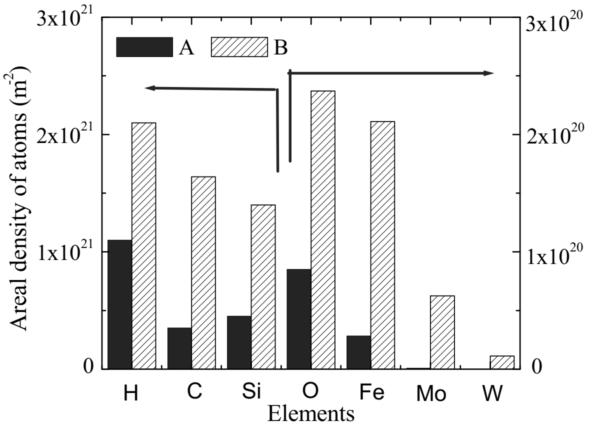

Fig. 2. The areal density of the displacements, deposited metals and retained hydrogen atoms in the SiC crystals..