

§104. 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.

The samples used as the material probe were mainly SiC and W single crystals. The SiC plates were commercially available 6H-SiC single crystals. The W disks were 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 hot-ion-mode plasmas with 10~40 shots of a typical pulse with 0.4 sec, varying parameters of ion energy (150-350 eV). After the plasma irradiation, each sample was analyzed by Rutherford backscattering spectrometry (RBS) and by the elastic recoil detection (ERD) methods for deposited metal impurities and retained hydrogen atoms in the surface layer of it, using a 1.7 MeV tandem accelerator. The RBS analysis combined with a channeling condition was also performed to evaluate the plasma induced damage profiles in the crystals. The H and O ion implantation to the samples prior to the plasma exposure was also performed to study the pre-damaged effects on the hydrogen retention.

After the plasma irradiation, an oxide layer consisting of Fe, Cr, Ni, Mo and W was formed on the SiC crystal. The hydrogen was retained in both the oxide layer and the substrate. The integrated number of the metal elements and hydrogen was estimated to be the order of 10^{19} ~ 10^{20} m^{-2} and 10^{21} m^{-2} , respectively. On the irradiated SiC sample, colored area was clearly visible as concentric circles. According to the ion beam analysis sweeping across the diameter of the irradiated area with an interval of 1mm, the integrated amount of the deposited metal atoms showed a maximum at the center of the circle and decreased toward the edge as shown in Fig. 1. On the other hand, relatively flat distribution was found in the whole irradiated area for displaced Si atoms, and even higher at the edge where little deposited metal atoms was observed.

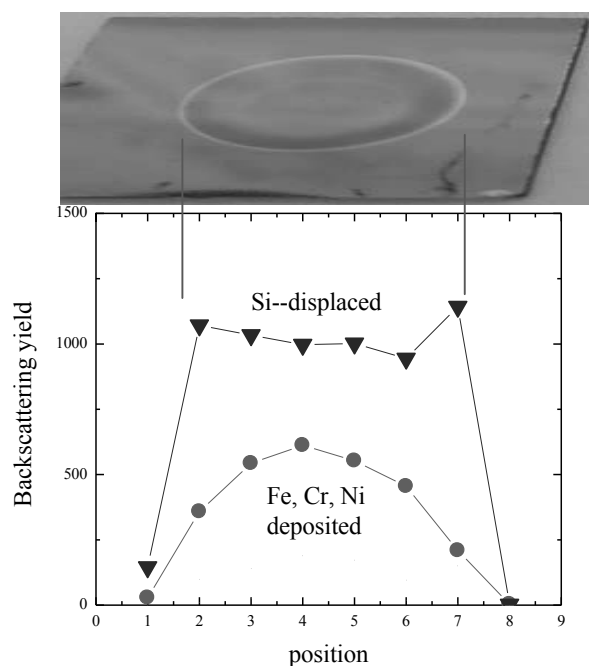


Fig. 1. The irradiated spot on SiC crystal (upper). the amount of the deposited metal atoms and displaced Si atoms obtained by RBS scanning across the diameter of the circular area of the irradiated SiC surface.

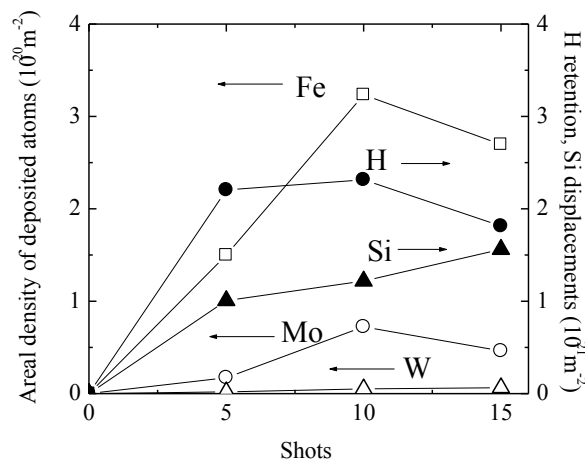


Fig. 2. The deposition of metal, H retention and damage plotted as a function of the number of discharges with 0.4 s.

The areal density of the deposited metal atoms and retained H atoms saturated and slightly diminished after 10 shots of 0.4 s discharges as shown in Fig. 2. The decrease of the oxide layer is attributed to the reductive reaction. The incident hydrogen ions were totally stopped in the deposited layer whose thickness was comparable to the projected ranges of them. On the contrary, the number of damaged Si atoms increased up to 15 shots. When the deposited layer reduced, incident hydrogen reached to the SiC substrate over again, creating displacements. The hydrogen retention was strongly enhanced in W crystals when the pre-damaged layer was formed in the near surface. The pre-damaged layer far beyond the ranges of the plasma ions did not influence the trapping behavior of the hydrogen in both W and SiC crystals.