§31. Quantitative Evaluation of Hydrogen Isotope Retention under Complex Ion Irradiation on PFM

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i) Introduction

Tungsten is considered to be a candidate for plasma facing materials (PFMs) in the International Thermonuclear Experimental Reactor (ITER) due to these high conductivity and high melting point. During the plasma operations, carbon, which will be contaminated by the impurities in the vacuum vessel, will be sputtered by the plasma and sputtered carbon will be mixed into the plasma. It is predicted that the tungsten – carbon mixed layer is formed on tungsten by energetic carbon implantation during the plasma operation, which will cause higher hydrogen isotope retention and hydrogen isotope release as hydrocarbons by chemical sputtering processes. It is suggested that hydrogen isotope retention and release in the tungsten – carbon mixed layer will affect tritium inventory in plasma facing materials. Therefore, the mass balance between hydrogen isotope retention behaviors and dynamic sputtering behaviors of hydrocarbons under hydrogen isotopes and carbon implantation environment were evaluated. In this study, spattering particle behavior for C^+ implanted tungsten during D_2^+ implantation, namely C^+ and D_2^+ sequential implantation, were investigated.

ii) Experimental

The disk-type tungsten samples with 10 mm diameter and 0.5 mm thickness were cut off from a rod of tungsten prepared under stress-relieved conditions (heated at 1173 K) and purchased from Allied Material Co. Ltd. The samples were polished mechanically by SiC abrasive paper and, 1 μm and 3 μm diamond suspensions. The sample was preheated at 1173 K for 30 minutes under ultrahigh vacuum to remove the surface impurities and damages introduced during the polishing processes. After preheating, C^+ implantation was performed. The implantation flux, fluence and energy of C^+ were fixed to 1.0×10^{17} C^+ m^{-2} s^{-1}, 1.0×10^{21} C^+ m^{-2} and 10 keV, respectively. Thereafter, 3 keV D_2^+ implantation was performed for the C^+ implanted tungsten at various fluences of $(0.03\text{-}1.8)\times10^{22}$ D^+ m^{-2}. Thermal Desorption Spectroscopy (TDS) measurements were carried out for these C^+-D_2^+ implanted samples. Furthermore, sputtering particle measurement was performed during the C^+ and D_2^+ sequential implantation up to the fluence of 1.0×10^{22} D^+ m^{-2} for C^+ irradiated tungsten. The X-ray Photoelectron Spectroscopy (XPS) was also performed to elucidate chemical states of tungsten surface.

iii) Results and discussion

Figure shows a result of sputtered particles measurement in C^+ - D_2^+ sequential implanted tungsten. Sputtered deuterium as D and hydrocarbons like CD_2, CD_3 and CD_4 was observed. The release of D would be caused by dynamic reflection process at the surface of tungsten. It was clear that major hydrocarbon species sputtered from C^+ implanted tungsten was CD_4. The D release rate was gradually decreased in the D^+ fluence up to 0.2×10^{22} D^+ m^{-2} and finally reached to constant. The CD_4 emission was hardly observed in the initial D_2^+ implantation. As the D release was decreased, the CD_4 emission was clearly increased in the D^+ fluence up to 0.2×10^{22} D^+ m^{-2}, indicating that the some of D was trapped by C to form C-D bond. After the saturation of D trapped by surface, the CD_4 emission was observed, which is the consistent with the TDS result. In addition, the formation of W-C mixed layer refrained the deuterium diffusion toward the bulk, which would enhance the deuterium accumulation near the surface region. Therefore, it was considered that CD_4 sputtering rate was controlled by the deuterium concentration in the surface region of tungsten and large amount of CD_4 was released just after the saturation of deuterium near surface region.

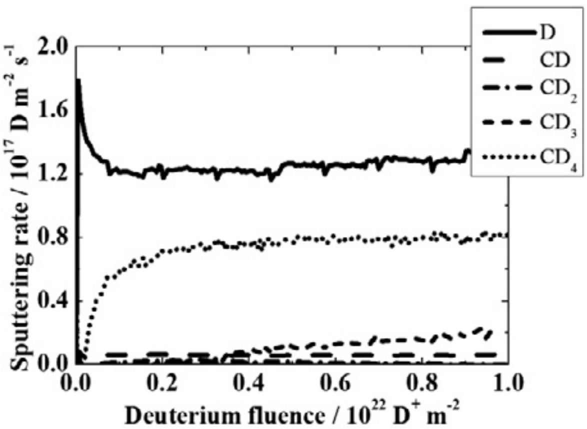

Fig. Deuterium sputtering behavior for the C^+ pre-implanted tungsten.