§29. 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 ITER due to higher conductivity and higher melting point. During the plasma operations, carbon, which will be retained in the vacuum vessel as the impurities, will be sputtered by the plasma and will be mixed into the plasma. Therefore, the tungsten – carbon mixed layer will be formed on tungsten surface by energetic carbon implantation during the plasma operation, which will cause the enhancement of hydrogen isotope retention and the hydrogen isotope may be released as hydrocarbons by the chemical sputtering process. It is suggested that the hydrogen isotope retention and release in the tungsten – carbon mixed layer will affect tritium inventory in plasma facing materials. In the previous study, it was clarified that the sputtering rate of CD_4 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 of tungsten. In this study, spattering particle behaviors for C^+ implanted tungsten, tungsten carbide (WC) and highly oriented pyrolytic graphite (HOPG) during H_2^+ implantation were evaluated.

ii) Experimental

The disk-type tungsten (Allied Material Co. Ltd.) cut from a rod of tungsten prepared under stress-relieved conditions. This sample was polished mechanically by SiC abrasive papers and the size of 1-3 μm diamond suspensions. These samples were preheated at 1173 K for 30 minutes under ultrahigh vacuum to remove the impurities in sample and damages introduced during the polishing processes. After preheating, the C^+ was implanted into tungsten. The ion 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, sputtering particle measurement for carbon implanted tungsten during the H_2^+ implantation was performed. The H_2^+ was implanted into tungsten with ion flux and energy of 1.0×10^{18} H^+ m^{-2} s^{-1} and 3 keV H_2^+, respectively. The sputtering particle measurements for WC (Allied Material Co. Ltd.) and HOPG (Pechiney Co.) samples during H_2^+ implantation was also performed in the same manner of tungsten.

iii) Results and discussion

Figure shows the release rates of hydrocarbons for C^+ implanted W, WC and HOPG, during H_2^+ implantation. Most of hydrogen for WC and HOPG was released as CH_4. On the other hand, major hydrocarbons for C^+ implanted W were CH_3 and CH_2. In the previous studies, C-D bonds were formed for HOPG and WC by the existance of the dangling bonds and vacancies into them, which may undergo the process of non-thermal equilibrium and/or the carbon adjacent to vacancies undergo the process of thermal equilibrium. For C^+ implanted tungsten, C-D bond was not formed, suggesting that carbon introduced in tungsten was not able to form the dangling bonds. The solubility of deuterium in tungsten is less than that in HOPG and the reflection rate of hydrogen ion irradiated into tungsten is higher than that into HOPG and WC. It can be concluded that hydrogen irradiated into HOPG and WC were released as CH_4 due to the existane of large amount of trapped hydrogen. Furthermore, hydrogen implanted into C^+ irradiated tungsten was released as CH_2 and CH_3.

It was suggested that the species of sputtering molecule was affected by the chemical state of carbon and the density of hydrogen in the sample.

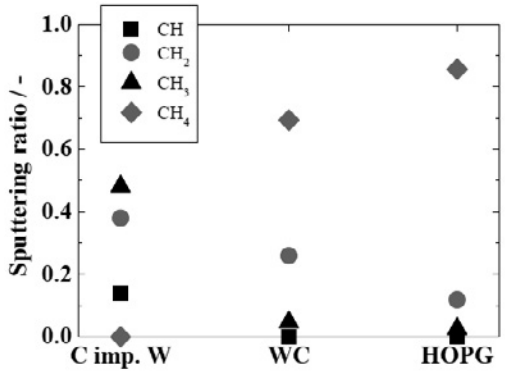

Fig. The rate of sputtered hydrocarbons for C^+ implanted W, WC and HOPG.