§3. Deuterium Retention in Stainless Steel and D-Release under He-Gas-Plasma Exposure

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Understanding and control of plasma-wall interaction is a key for achievement of long-life fusion plasma and plasma-wall conditioning is an important process. In this study, we have investigated retention of deuterium in stainless steel (SUS) under D_2 plasma exposure and release of deuterium from SUS under He plasma exposure.

SUS samples were exposed to D_2 plasma. The energy of D was 300 eV and the fluence was $4x10^{18}$ cm^{-2}. The samples were followed by exposure to He plasma with the energy of 50, 300 and 600 eV to a fluence of 0.2, 8, $2x10^{18}$ cm^{-2}, respectively. The plasma exposure was performed by using a linear-divertor-plasma simulator (NAGDIS-II). The temperature during the plasma exposure was kept less than 200 ^{o}C. The amount of D was analyzed by using nuclear reaction analysis (NRA), D(^{3}He,α)H with ^{3}He-energy of 0.7 MeV. In NRA, SUS is approximated by Fe with the density of 7.86 gcm^{-3} and the stopping power is taken after [1]. NRA cross section is taken from [2]. Because of poor depth resolution of the NRA, no meaningful information on the depth profile can be obtained and only total amount of D is evaluated.

The amount of D retained in SUS is summarized in Table 1. NRA measurements were performed more than twice, on the different sample positions for each sample and it appears that amount of D scatters by a factor of 2. The average values are given in Table 1. It is found that D retention in SUS for D_2 plasma exposure is much smaller than the fluence and that in oxide such as TiO_2 [3]. D retention of 0.39 $x10^{15}$ cm^{-2} for the exposure condition mentioned above in the present study appears to be comparable with the reported value of D retention of $0.85x10^{15}$ cm^{-2} at the energy of 15 eV and fluence of $2x10^{20}$ cm^{-2}. Furthermore, D-retention in SUS for D with thermal energy is ~1 $x10^{15}$ cm^{-2} [4]. These imply saturation and little energy dependence. It is speculated that the D energy is not sufficient to generate effective damage for D trapping in SUS. The maximum transfer energy is 40 eV for 300 eV D impact on Fe and this value is scarcely larger than the displacement threshold energy of 17 eV for Fe [5]. The projected range of D (300 eV) in Fe is ~3 nm [1] and D-trapping is sensitive to the condition of the very near surface. D may be released at room temperature as D-release from Ti metal [3]. Thermal D-release from SUS is to be investigated.

It is found that the amount of retained D for post-He-gas-plasma exposure is slightly larger than that for D-plasma exposure only. Assuming that D-release takes place for SUS, it is speculated that the post-exposure to He plasma more effectively create damage for D-trapping than D-plasma exposure only and suppress D-release. This speculation would be the case. The maximum transfer energy is 12.5, 75 and 150 eV for impact of He with 50, 300 and 600 eV on Fe, respectively. In view of the kinematics, damage creation is not anticipated for 50 eV He impact on Fe, but for 300 and 600 eV He impact. For these cases, D-retention is slightly larger than that for post-He-plasma exposure at 50 eV.

Table 1 Summary of D retention in SUS. In sample column, D means that SUS is exposed to D plasma and that D+He(50), D+He(300) and D+He(600) mean that SUS are exposed to He at energy of 50, 300 and 600 eV after the D plasma exposure.

Sample	Retention (10^{15} cm^{-2})
D	0.39
D+He(50)	0.42
D+He(300)	0.93
D+He(600)	0.62

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